Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering

Contents

Unit 1: Analytical Methods for Engineers

Unit code: A/601/1401

Level: 4

Credit value: 15

Aim

This unit will provide the analytical knowledge and techniques needed to carry out a range of engineering tasks and will provide a base for further study of engineering mathematics.

Unit abstract

This unit enables learners to develop previous mathematical knowledge obtained at school or college and use fundamental algebra, trigonometry, calculus, statistics and probability for the analysis, modelling and solution of realistic engineering problems.

Learning outcome 1 looks at algebraic methods, including polynomial division, exponential, trigonometric and hyperbolic functions, arithmetic and geometric progressions in an engineering context and expressing variables as power series.

The second learning outcome will develop learners' understanding of sinusoidal functions in an engineering concept such as AC waveforms, together with the use of trigonometric identities.

The calculus is introduced in learning outcome 3, both differentiation and integration with rules and various applications.

Finally, learning outcome 4 should extend learners' knowledge of statistics and probability by looking at tabular and graphical representation of data; measures of mean, median, mode and standard deviation; the use of linear regression in engineering situations, probability and the Normal distribution.

Learning outcomes

On successful completion of this unit a learner will:

1 Be able to analyse and model engineering situations and solve problems using algebraic methods

2 Be able to analyse and model engineering situations and solve problems using trigonometric methods

3 Be able to analyse and model engineering situations and solve problems using calculus

4 Be able to analyse and model engineering situations and solve problems using statistics and probability.

Unit content

1 **Be able to analyse and model engineering situations and solve problems using algebraic methods**

Algebraic methods: polynomial division; quotients and remainders; use of factor and remainder theorem; rules of order for partial fractions (including linear, repeated and quadratic factors); reduction of algebraic fractions to partial fractions

Exponential, *trigonometric and hyperbolic functions*: the nature of algebraic functions; relationship between exponential and logarithmic functions; reduction of exponential laws to linear form; solution of equations involving exponential and logarithmic expressions; relationship between trigonometric and hyperbolic identities; solution of equations involving hyperbolic functions

Arithmetic and geometric: notation for sequences; arithmetic and geometric progressions; the limit of a sequence; sigma notation; the sum of a series; arithmetic and geometric series; Pascal's triangle and the binomial theorem

Power series: expressing variables as power series functions and use series to find approximate values eg exponential series, Maclaurin's series, binomial series

2 **Be able to analyse and model engineering situations and solve problems using trigonometric methods**

Sinusoidal functions: review of the trigonometric ratios; Cartesian and polar co-ordinate systems; properties of the circle; radian measure; sinusoidal functions

Applications: angular velocity, angular acceleration, centripetal force, frequency, amplitude, phase, the production of complex waveforms using sinusoidal graphical synthesis, AC waveforms and phase shift

Trigonometric identities: relationship between trigonometric and hyperbolic identities; double angle and compound angle formulae and the conversion of products to sums and differences; use of trigonometric identities to solve trigonometric equations and simplify trigonometric expressions

3 **Be able to analyse and model engineering situations and solve problems using calculus**

Calculus: the concept of the limit and continuity; definition of the derivative; derivatives of standard functions; notion of the derivative and rates of change; differentiation of functions using the product, quotient and function of a function rules; integral calculus as the calculation of area and the inverse of differentiation; the indefinite integral and the constant of integration; standard integrals and the application of algebraic and trigonometric functions for their solution; the definite integral and area under curves

Further differentiation: second order and higher derivatives; logarithmic differentiation; differentiation of inverse trigonometric functions; differential coefficients of inverse hyperbolic functions

Further integration: integration by parts; integration by substitution; integration using partial fractions

Applications of the calculus: eg maxima and minima, points of inflexion, rates of change of temperature, distance and time, electrical capacitance, rms values, electrical circuit analysis, AC theory, electromagnetic fields, velocity and acceleration problems, complex stress and strain, engineering structures, simple harmonic motion, centroids, volumes of solids of revolution, second moments of area, moments of inertia, rules of Pappus, radius of gyration, thermodynamic work and heat energy

Engineering problems: eg stress and strain, torsion, motion, dynamic systems, oscillating systems, force systems, heat energy and thermodynamic systems, fluid flow, AC theory, electrical signals, information systems, transmission systems, electrical machines, electronics

4 **Be able to analyse and model engineering situations and solve problems using statistics and probability**

Tabular and graphical form: data collection methods; histograms; bar charts; line diagrams; cumulative frequency diagrams; scatter plots

Central tendency and dispersion: the concept of central tendency and variance measurement; mean; median; mode; standard deviation; variance and interquartile range; application to engineering production

Regression, *linear correlation*: determine linear correlation coefficients and regression lines and apply linear regression and product moment correlation to a variety of engineering situations

Probability: interpretation of probability; probabilistic models; empirical variability; events and sets; mutually exclusive events; independent events; conditional probability; sample space and probability; addition law; product law; Bayes' theorem

Probability distributions: discrete and continuous distributions, introduction to the binomial, Poisson and normal distributions; use of the normal distribution to estimate confidence intervals and use of these confidence intervals to estimate the reliability and quality of appropriate engineering components and systems

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Be able to analyse and model engineering situations and solve problems using algebraic methods	1.1 determine the quotient and remainder for algebraic fractions and reduce algebraic fractions to partial fractions 1.2 solve engineering problems that involve the use and solution of exponential, trigonometric and hyperbolic functions and equations 1.3 solve scientific problems that involve arithmetic and geometric series 1.4 use power series methods to determine estimates of engineering variables expressed in power series form
LO2 Be able to analyse and model engineering situations and solve problems using trigonometric methods	2.1 use trigonometric functions to solve engineering problems 2.2 use sinusoidal functions and radian measure to solve engineering problems 2.3 use trigonometric and hyperbolic identities to solve trigonometric equations and to simplify trigonometric expressions
LO3 Be able to analyse and model engineering situations and solve problems using calculus	3.1 differentiate algebraic and trigonometric functions using the product, quotient and function of function rules 3.2 determine higher order derivatives for algebraic, logarithmic, inverse trigonometric and inverse hyperbolic functions 3.3 integrate functions using the rules, by parts, by substitution and partial fractions 3.4 analyse engineering situations and solve engineering problems using calculus
LO4 Be able to analyse and model engineering situations and solve problems using statistics and probability	4.1 represent engineering data in tabular and graphical form 4.2 determine measures of central tendency and dispersion 4.3 apply linear regression and product moment correlation to a variety of engineering situations 4.4 use the normal distribution and confidence intervals for estimating reliability and quality of engineering

	components and systems.

Guidance

Links

This unit can be linked with the core units and other principles and applications units within the programme. It will also form the underpinning knowledge for the study of further mathematical units such as *Unit 35: Further Analytical Methods for Engineers, Unit 59: Advanced Mathematics for Engineering.*

Entry requirements for this unit are at the discretion of the centre. However, it is strongly advised that learners should have completed the BTEC National unit *Mathematics for Engineering Technicians* or equivalent. Learners who have not attained this standard will require appropriate bridging studies.

Essential requirements

There are no essential resources for this unit.

Employer engagement and vocational contexts

The delivery of this unit will benefit from centres establishing strong links with employers willing to contribute to the delivery of teaching, work-based placements and/or detailed case study materials.

Unit 2: Engineering Science

Unit code: L/601/1404

Level: 4

Credit value: 15

Aim

This unit aims to provide learners with an understanding of the mechanical and electrical principles that underpin mechanical and electrically focused engineering systems.

Unit abstract

Engineers, no matter from what discipline, need to acquire a fundamental understanding of the mechanical and electrical principles that underpin the design and operation of a large range of engineering equipment and systems.

This unit will develop learners' understanding of the key mechanical and electrical concepts that relate to all aspects of engineering.

In particular, learners will study elements of engineering statics including the analysis of beams, columns and shafts. They will then be introduced to elements of engineering dynamics, including the behavioural analysis of mechanical systems subject to uniform acceleration, the effects of energy transfer in systems and to natural and forced oscillatory motion.

The electrical system principles in learning outcome 3 begin by refreshing learners' understanding of resistors connected in series/parallel and then developing the use of Ohm's law and Kirchhoff's law to solve problems involving at least two power sources. Circuit theorems are also considered for resistive networks only together with a study of the characteristics of growth and decay of current/voltage in series C-R and L-R circuits.

The final learning outcome develops learners' understanding of the characteristics of various AC circuits and finishes by considering an important application – the transformer.

Learning outcomes

On successful completion of this unit a learner will:

1 Be able to determine the behavioural characteristics of elements of static engineering systems

2 Be able to determine the behavioural characteristics of elements of dynamic engineering systems

3 Be able to apply DC theory to solve electrical and electronic engineering problems

4 Be able to apply single phase AC theory to solve electrical and electronic engineering problems.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017

Unit content

1 **Be able to determine the behavioural characteristics of elements of static engineering systems**

Simply supported beams: determination of shear force; bending moment and stress due to bending; radius of curvature in simply supported beams subjected to concentrated and uniformly distributed loads; eccentric loading of columns; stress distribution; middle third rule

Beams and columns: elastic section modulus for beams; standard section tables for rolled steel beams; selection of standard sections eg slenderness ratio for compression members, standard section and allowable stress tables for rolled steel columns, selection of standard sections

Torsion in circular shafts: theory of torsion and its assumptions eg determination of shear stress, shear strain, shear modulus; distribution of shear stress and angle of twist in solid and hollow circular section shafts

2 **Be able to determine the behavioural characteristics of elements of dynamic engineering systems**

Uniform acceleration: linear and angular acceleration; Newton's laws of motion; mass moment of inertia and radius of gyration of rotating components; combined linear and angular motion; effects of friction

Energy transfer: gravitational potential energy; linear and angular kinetic energy; strain energy; principle of conservation of energy; work-energy transfer in systems with combine linear and angular motion; effects of impact loading

Oscillating mechanical systems: simple harmonic motion; linear and transverse systems; qualitative description of the effects of forcing and damping

3 **Be able to apply DC theory to solve electrical and electronic engineering problems**

DC electrical principles: refresh idea of resistors in series and parallel; use of Ohm's and Kirchhoff's laws; voltage and current dividers; review of motor and generator principles eg series, shunt; circuit theorems eg superposition, Thevenin, Norton and maximum power transfer for resistive circuits only; fundamental relationships eg resistance, inductance, capacitance, series C-R circuit, time constant, charge and discharge curves of capacitors, L-R circuits

4 **Be able to apply single phase AC theory to solve electrical and electronic engineering problems**

AC electrical principles: features of AC sinusoidal wave form for voltages and currents; explanation of how other more complex wave forms are produced from sinusoidal wave forms; R, L, C circuits eg reactance of R, L and C components, equivalent impedance and admittance for R-L and R-C circuits; high or low pass filters; power factor; true and apparent power; resonance for circuits containing a coil and capacitor connected either in series or parallel; resonant frequency; Q-factor of resonant circuit; transformer fundamentals: construction eg double wound; transformation ratio; equivalent circuit; unloaded transformer; resistance (impedance) matching; transformer losses; applications eg current transformers, voltage transformers

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Be able to determine the behavioural characteristics of elements of static engineering systems	1.1 determine distribution of shear force, bending moment and stress due to bending in simply supported beams 1.2 select standard rolled steel sections for beams and columns to satisfy given specifications 1.3 determine the distribution of shear stress and the angular deflection due to torsion in circular shafts
LO2 Be able to determine the behavioural characteristics of elements of dynamic engineering systems	2.1 determine the behaviour of dynamic mechanical systems in which uniform acceleration is present 2.2 determine the effects of energy transfer in mechanical systems 2.3 determine the behaviour of oscillating mechanical systems
LO3 Be able to apply DC theory to solve electrical and electronic engineering problems	3.1 solve problems using Kirchhoff's laws to calculate currents and voltages in circuits 3.2 solve problems using circuit theorems to calculate currents and voltages in circuits 3.3 solve problems involving current growth/decay in an L-R circuit and voltage growth/decay in a C-R circuit
LO4 Be able to apply single phase AC theory to solve electrical and electronic engineering problems	4.1 recognise a variety of complex waveforms and explain how they are produced from sinusoidal waveforms 4.2 apply AC theory to solve problems on R, L, C circuits and components 4.3 apply AC theory to solve problems involving transformers.

Guidance

Links

This unit may be linked with *Unit 1: Analytical Methods for Engineers*.

Successful completion of this unit would enable learners to meet, in part, the Incorporated Engineer (IEng) requirements laid down in the UK Engineering Council Standard for Professional Engineering Competence (UK-SPEC) Competence A2, ‘Use appropriate scientific, technical or engineering principles’.

Essential requirements

Learners will need access to suitable mechanical and electrical laboratory equipment.

Employer engagement and vocational contexts

Liaison with employers would prove of benefit to centres, especially if they are able to offer help with the provision of suitable mechanical or electrical systems/equipment that demonstrate applications of the principles.

Unit 3: Project Design, Implementation and Evaluation

Unit code: L/601/0995

Level: 5

Credit value: 20

Aim

To develop learners' skills of independent enquiry by undertaking a sustained investigation of direct relevance to their vocational, academic and professional development.

Unit abstract

This unit provides opportunities for learners to develop skills in decision making, problem solving and communication, integrated with the skills and knowledge developed in many of the other units within the programme to complete a realistic project.

It requires learners to select, plan, implement and evaluate a project and finally present the outcomes, in terms of the process and the product of the project. It also allows learners to develop the ability to work individually and/or with others, within a defined timescale and given constraints, to produce an acceptable and viable solution to an agreed brief.

If this is a group project, each member of the team must be clear about their responsibilities at the start of the project and supervisors must ensure that everyone is accountable for each aspect of the work and makes a contribution to the end result.

Learners must work under the supervision of programme tutors or work-based managers.

Learning outcomes

On successful completion of this unit a learner will:

1 Be able to formulate a project

2 Be able to implement the project within agreed procedures and to specification

3 Be able to evaluate the project outcomes

4 Be able to present the project outcomes.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017 © Pearson Education Limited 2017

Unit content

1 **Be able to formulate a project**

Project selection: researching and reviewing areas of interest; literature review; methods of evaluating feasibility of projects, initial critical analysis of the outline specification, selection of project option, initiating a project logbook/diary, estimating costs and resource implications, identifying goals and limitations, value of project, rationale for selection, agree roles and allocate responsibilities (individually with tutor/supervisor and within project group if appropriate)

Project specifications: developing and structuring a list of requirements relevant to project specifications eg costs, timescales, scale of operation, standards, legislation, ethics, sustainability, quality, fitness-for-purpose, business data, resource implications

Procedures: planning and monitoring methods, operating methods, lines of communication, risk analysis, structure of groups and collaborative working eg learner groups or roles and responsibilities within a work-based project, targets and aims

Project plan: production of a plan for the project including timescales, deliverables, milestones, quality assurance systems and quality plans, and monitoring progress

2 **Be able to implement the project within agreed procedures and to specification**

Implement: proper use of resources, working within agreed timescale, use of appropriate techniques for generating solutions, monitoring development against the agreed project plan, maintaining and adapting project plan where appropriate

Record: systematic recording of relevant outcomes of all aspects and stages of the project to agreed standards

3 **Be able to evaluate the project outcomes**

Evaluation techniques: detailed analysis of results, conclusions and recommendations, critical analysis against the project specification and planned procedures, use of appropriate evaluation techniques, application of project evaluation and review techniques (PERT), opportunities for further studies and developments

Interpretation: use of appropriate techniques to justify project progress and outcomes in relation to the original agreed project specification

Further consideration: significance of project; application of project results; implications; limitations of the project; improvements; recommendations for further consideration

4 **Be able to present the project outcomes**

Record of procedures and results: relevant documentation of all aspects and stages of the project

Format: professional delivery format appropriate to the audience; use of appropriate media

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Be able to formulate a project	1.1 formulate and record possible outline project specifications 1.2 identify the factors that contribute to the process of project selection 1.3 produce a specification for the agreed project 1.4 produce an appropriate project plan for the agreed project
LO2 Be able to implement the project within agreed procedures and to specification	2.1 match resources efficiently to the project 2.2 undertake the proposed project in accordance with the agreed specification. 2.3 organise, analyse and interpret relevant outcomes
LO3 Be able to evaluate the project outcomes	3.1 use appropriate project evaluation techniques 3.2 interpret and analyse the results in terms of the original project specification 3.3 make recommendations and justify areas for further consideration
LO4 Be able to present the project outcomes	4.1 produce a record of all project procedures used 4.2 use an agreed format and appropriate media to present the outcomes of the project to an audience.

Guidance

Links

This unit is suitable for use by all sectors and should utilise the full range of skills developed through study of other units in the programme. These include planning, practical work, data handling and processing, analysis and presentation.

The knowledge applied may link to one particular unit or to a number of other units.

Essential requirements

The required resources will vary significantly with the nature of the project. The identification of the equipment and materials required, and the establishment of their availability, is a vital part of the planning phase. Learners should therefore have access to a wide variety of physical resources and data sources relevant to the project. Tutors should ensure that learners do not embark on work that cannot succeed because of lack of access to the required resources.

Employer engagement and vocational contexts

Centres should try to establish relationships with appropriate organisations in order to bring realism and relevance to the project.

Unit 4: Mechanical Principles

Unit code: F/601/1450

Level: 5

Credit value: 15

Aim

This unit aims to develop learners' understanding of an extended range of mechanical principles that underpin the design and operation of mechanical engineering systems.

Unit abstract

This unit will develop learners' understanding of complex loading systems and will provide an introduction to the concept of volumetric strain and the relationship between elastic constants. The expressions derived for linear and volumetric strain then form a basis for determining dimensional changes in loaded cylinders.

The unit will build upon learners' existing knowledge of the relationship between the distribution of shear force and bending moment in loaded beams, to include the relationship between bending moment, slope and deflection.

Learners will analyse the use of mechanical power transmission systems, both individually and in the combinations that are used in practical situations. Learners' knowledge of rotating system elements is further extended through an investigation of the dynamic characteristics of the slider-crank and four-bar linkage. The balancing of rotating systems is also investigated, together with the determination of flywheel mass and size to give sufficiently smooth operating conditions.

Learning outcomes

On successful completion of this unit a learner will:

1 Be able to determine the behavioural characteristics of materials subjected to complex loading systems

2 Be able to determine the behavioural characteristics of loaded beams and cylinders

3 Be able to determine the dynamic parameters of power transmission system elements

4 Be able to determine the dynamic parameters of rotating systems.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017

Unit content

1 **Be able to determine the behavioural characteristics of materials subjected to complex loading systems**

Relationship: definition of Poisson’s Ratio; typical values of Poisson’s Ratio for common engineering materials

Two- and three-dimensional loading: expressions for strain in the x, y and z-directions; calculation of changes in dimensions

Volumetric strain: expression for volumetric strain; calculation of volume change

Elastic constants: definition of Bulk Modulus; relationship between Modulus of Elasticity; Shear Modulus; Bulk Modulus and Poisson’s Ratio for an elastic material

2 **Be able to determine the behavioural characteristics of loaded beams and cylinders**

Relationships: slope $i = \frac{1}{E1}\int Mdx$

deflection $y = \frac{1}{E1}\iint Mdxdx$

Loaded beams: slope and deflection for loaded beams eg cantilever beams carrying a concentrated load at the free end or a uniformly distributed load over the entire length, simply supported beams carrying a central concentrated load or a uniformly distributed load over the entire length

Stresses in thin-walled pressure vessels: circumferential hoop stress and longitudinal stress in cylindrical and spherical pressure vessels subjected to internal and external pressure eg compressed-air receivers, boiler steam drums, submarine hulls, condenser casings; factor of safety; joint efficiency

Stresses in thick-walled cylinders: circumferential hoop stress, longitudinal stress and radial stress in thick-walled cylinders subjected to pressure eg hydraulic cylinders, extrusion dies, gun barrels; Lame’s theory; use of boundary conditions and distribution of stress in the cylinder walls

3 **Be able to determine the dynamic parameters of power transmission system elements**

Belt drives: flat and v-section belts; limiting coefficient friction; limiting slack and tight side tensions; initial tension requirements; maximum power transmitted

Friction clutches: flat single and multi-plate clutches; conical clutches; coefficient of friction; spring force requirements; maximum power transmitted by constant wear and constant pressure theories; validity of theories

Gear trains: simple, compound and epicycle gear trains; velocity ratios; torque, speed and power relationships; efficiency; fixing torques

4 **Be able to determine the dynamic parameters of rotating systems**

Plane mechanisms: slider crank and four bar linkage mechanisms; production of vector diagrams and determination of kinetic characteristics

Balancing: single plane and multi-plane rotating mass systems; Dalby's method for determination of out-of-balance forces and couples and the required balancing masses

Flywheels: angular momentum; kinetic energy; coefficient of fluctuation of speed; coefficient of fluctuation of energy; calculation of flywheel mass/dimensions to give required operating conditions

Effects of coupling: conservation of angular momentum; common final velocity and energy loss due to coupling of two freely rotating systems

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Be able to determine the behavioural characteristics of materials subjected to complex loading systems	1.1 apply the relationship between longitudinal and transverse strain to determine the dimensional effects of uniaxial loading on a given material 1.2 determine the effects of two-dimensional and three-dimensional loading on the dimensions of a given material 1.3 determine volumetric strain and change in volume due to three-dimensional loading 1.4 apply the relationship between elastic constants
LO2 Be able to determine the behavioural characteristics of loaded beams and cylinders	2.1 apply the relationship between bending moment, slope and deflection to determine the variation of slope and deflection along a simply supported beam 2.2 determine the principal stresses that occur in a thin-walled cylindrical pressure vessel 2.3 determine the distribution of the stresses that occur in a pressurised thick-walled cylinder
LO3 Be able to determine the dynamic parameters of power transmission system elements	3.1 determine the dynamic parameters of a belt drive 3.2 determine the dynamic parameters of a friction clutch 3.3 determine the holding torque and power transmitted through compound and epicyclic gear trains
LO4 Be able to determine the dynamic parameters of rotating systems	4.1 determine the parameters of a slider-crank and a four-bar linkage mechanism 4.2 determine the balancing masses required to obtain dynamic equilibrium in a rotating system 4.3 determine the energy storage requirements of a flywheel 4.4 determine the dynamic effects of coupling two freely rotating systems.

Guidance

Links

This unit can be linked with *Unit 1: Analytical Methods for Engineers*, *Unit 2: Engineering Science*, *Unit 35: Further Analytical Methods for Engineers* and *Unit 60: Dynamics of Machines*.

Essential requirements

Sufficient laboratory/test equipment will need to be available to support a range of practical investigations.

Employer engagement and vocational contexts

Liaison with employers would prove of benefit to centres, especially if they are able to offer help with the provision of suitable mechanical systems/equipment that can be used to demonstrate applications of the principles.

Unit 5: Electrical and Electronic Principles

Unit code: R/601/1453

Level: 5

Credit value: 15

Aim

This unit provides an understanding of electrical and electronic principles used in a range of engineering careers and provides the basis for further study of more specialist areas of electrical/electronic engineering.

Unit abstract

Circuits and their characteristics are fundamental to any study of electrical and electronic engineering and therefore a good understanding is important to any engineer.

The engineer must be able to take complex electrical circuit problems, break them down into acceptable elements and apply techniques to solve or analyse the characteristics. Additionally, fine tuning of the circuits can be performed to obtain required output dynamics.

This unit draws together a logical appreciation of the topic and offers a structured approach to the development of the broad learning required at this level. Learners will begin by investigating circuit theory and the related theorems to develop solutions to electrical networks.

In learning outcome 2 the concept of an attenuator is introduced by considering a symmetrical two-port network and its characteristics. The design and testing of both T and π networks is also covered.

Learning outcome 3 considers the properties of complex waveforms and Fourier analysis is used to evaluate the Fourier coefficients of a complex periodic waveform.

Finally, learning outcome 4 introduces the use of Laplace transforms as a means of solving first order differential equations used to model RL and RC networks, together with the evaluation of circuit responses to a step input in practical situations.

Learning outcomes

On successful completion of this unit a learner will:

1 Be able to apply electrical and electronic circuit theory

2 Be able to apply two-port network models

3 Understand the use of complex waves

4 Be able to apply transients in R-L-C circuits.

Unit content

1 **Be able to apply electrical and electronic circuit theory**

Transformation theorems: energy sources as constant-voltage and constant-current generators; Thévenin's and Norton's theorems; delta-star and star-delta transformation

Circuit theory: maximum power transfer conditions for resistive and complex circuits; mesh and nodal analysis; the principle of superposition

Magnetically coupled circuits: mutual inductance; the use of dot notation; equivalent circuits for transformers including the effects of resistive and reactive features

R-L-C tuned circuits: series and parallel resonant circuits; impedance; phase angle; dynamic resistance; Q-factor; bandwidth; selectivity and resonant frequency; the effects of loading on tuned circuit performance

2 **Be able to apply two-port network models**

Network models: symmetrical two-port network model; characteristic impedance, Z_o; propagation coefficient (expressed in terms of attenuation, α, and phase change ß); input impedance for various load conditions including $Z_L = Z_o$; relationship between the neper and the dB; insertion loss

Symmetrical attenuators: T and π attenuators; the expressions for R_o and α in terms of component values

3 **Understand the use of complex waves**

Properties: power factor; rms value of complex periodic waveforms

Analyse: Fourier coefficients of a complex periodic voltage waveform eg Fourier series for rectangular, triangular or half-wave rectified waveform, use of a tabular method for determining the Fourier series for a complex periodic waveform; use of a waveform analyser; use of an appropriate software package

4 **Be able to apply transients in R-L-C circuits**

Laplace transforms: definition of the Laplace transform of a function; use of a table of Laplace transforms

Transient analysis: expressions for component and circuit impedance in the s-plane; first order systems must be solved by Laplace (ie RL and RC networks); second order systems could be solved by Laplace or computer-based packages

Circuit responses: over, under, zero and critically damped response following a step input; zero initial conditions being assumed

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Be able to apply electrical and electronic circuit theory	1.1 calculate the parameters of AC equivalent circuits using transformation theorems 1.2 apply circuit theory techniques to the solution of AC circuit problems 1.3 analyse the operation of magnetically coupled circuits 1.4 use circuit theory to solve problems relating to series and parallel R-L-C tuned circuits
LO2 Be able to apply two-port network models	2.1 apply two-port network model to the solution of practical problems 2.2 design and test symmetrical attenuators against computer models
LO3 Understand the use of complex waves	3.1 calculate the properties of complex periodic waves 3.2 analyse complex periodic waves
LO4 Be able to apply transients in R-L-C circuits	4.1 use Laplace transforms for the transient analysis of networks 4.2 calculate circuit responses to a step input in practical situations.

Guidance

Links

This unit relies heavily on the use of mathematical analysis to support the underlying theory and practical work. Consequently it is assumed that *Unit 1: Analytical Methods for Engineers* has been taught previously or is being delivered in parallel. It may also be linked with *Unit 2: Engineering Science*.

Essential requirements

Learners will require access to a range of electronic test equipment, eg oscilloscopes, signal generators, etc.

Employer engagement and vocational contexts

Delivery of this unit will benefit from centres establishing strong links with employers willing to contribute to the delivery of teaching, work-based placements and/or detailed case study materials.

Unit 6: Health, Safety and Risk Assessment in Engineering

Unit code: A/601/1463

Level: 4

Credit value: 15

Aim

This unit aims to provide learners with an understanding of health and safety planning, implementation and legislation within an engineering environment.

Unit abstract

This unit has been designed to develop the learner's awareness of the principles, planning and implementation of health and safety practice within an industrial environment such as those to be found in engineering production, manufacture, services and maintenance and those in the chemical, transport and telecommunication engineering industries.

In particular, the selection, application and evaluation of safe working procedures, for operations appropriate to particular industrial activities, are first considered. Then current UK and EU health and safety legislation, the role of the inspectorate, safety audits and current codes of practice are covered. Next, risk is assessed and evaluated by identifying, rating and assessing the severity of hazards and recording all evidence and actions taken for future monitoring of these hazards. Finally, risk management activities are considered including the methods used for gathering evidence, disseminating information, complying with current regulations and implementing policy to minimise risk to life and property, for activities within a general engineering environment.

Learning outcomes

On successful completion of this unit a learner will:

1 Be able to select and apply safe working procedures to engineering operations

2 Understand the nature and use of current health and safety legislation

3 Be able to analyse engineering activities for the assessment of risk

4 Be able to manage and minimise risk to life, property and engineering activities within an industrial environment.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017

Unit content

1 **Be able to select and apply safe working procedures to engineering operations**

Protective clothing and equipment: selection and justification of protective clothing for given/chosen environments eg for chemical, temperature, crush resistance, noise protection, visor, goggle usage, electrical isolation, radioactive protection

Permit-to-work: evaluation of a range of permit-to-work systems; health and safety executive (HSE) guidance notes; hot-cold entry; buddy and plant identification systems; isolation requirements for given/chosen applications

Isolations: eg lock, multi-lock, blank off, removal, electrical, peg removal, linked valve key, isolation valves

Monitoring equipment: use of monitoring equipment to ensure/determine safe working environment eg noise, dust, fumes, temperature, movement, radiation; cost and usability

2 **Understand the nature and use of current health and safety legislation**

Current regulations: relevant and current UK and EU regulations eg COSHH, noise at work, pressure systems, manual handling, personal protective equipment, control of asbestos, Health and Safety at Work Act, management of health and safety at work, IEE wiring regulations, EMC directive; for typical engineering operations eg engineering production and manufacture, engineering services, materials handling, telecommunications and transportation

Role of HSE Inspectorate: span of authority; right of inspection; guidance notes and booklets

Safety audits: policies; record keeping; safety surveys; training; proformas; management commitment; planning and implementation

Codes of practice: use of applying technology for codes and regulations; awareness of relevant codes of practice eg HSE guidance, Occupational Exposure Standards

3 **Be able to analyse engineering activities for the assessment of risk**

Hazard: identification of potential hazards eg fire, noise, temperature, field of vision, fumes, moving parts, lighting, access, pressure, falling bodies, airborne debris, radiation and chemical hazards

Risk rating: matrix production eg low risk, moderate risk, substantial risk, high risk

Frequency and severity: evaluation of the rate of occurrence eg improbable, possible, occasional, frequent, regular, common; evaluation of severity eg definitions of consequence; level of injury eg graded (trivial, minor, major, multiple major, death, multiple death)

Record: production of proforma for each hazard, types of recording systems; employee training and company awareness; analysis of a system

4 **Be able to manage and minimise risk to life, property and engineering activities within an industrial environment**

Evidence: evaluation of evidence to support the likelihood of or reoccurrence of a risk; use of statistical data eg fatigue charts, working hours, temperature, lighting levels, noise, incorrect procedures, working practices, time of day

Implications: analysis and evaluation of the implications of the risk eg threat to life, injuries, property, environment, need to redesign, effect on company, effect on other companies; mandatory factory closure

Information: obtaining and use of data about the risk to others eg data sheets on substances, factory rules, codes of practice; safe working procedures, hazard identification eg hard hat area; training procedures for new staff and contractors

Minimising risk: how best to minimise risk eg control of known risks, guarding, covering, screening, encasing, design-out, disaster contingence planning

Implementation: identification of effective methods of control eg management policy, lines of communication, responsibility, safety committees and trade union input

Compliance: identification of the levels of knowledge of regulations and guidelines; mandatory compliance with current and relevant regulations eg Health and Safety at Work Act, Deposit of Poisonous Waste Act, EMC directive; working towards company risk assessment findings

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017 © Pearson Education Limited 2017

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Be able to select and apply safe working procedures to engineering operations	1.1 select and justify choice of protective clothing and equipment to ensure personal protection in a given environment 1.2 evaluate a range of permit-to-work systems and identify isolation requirements for given applications 1.3 use monitoring equipment to ensure the promotion of a safe working environment
LO2 Understand the nature and use of current health and safety legislation	2.1 identify industrial work areas where current regulations would apply and describe the role of the HSE inspectorate 2.2 implement a schedule for the setting-up of a safety audit system 2.3 select the relevant codes of practice to enhance safety
LO3 Be able to analyse engineering activities for the assessment of risk	3.1 identify a hazard and produce a risk rating 3.2 evaluate frequency and severity of an identified hazard 3.3 produce a hazard proforma for a given application 3.4 analyse a recording system that tracks and highlights potential hazards
LO4 Be able to manage and minimise risk to life, property and engineering activities within an industrial environment	4.1 evaluate evidence that would specify the existence of a risk or risks 4.2 analyse the implications of the risk and the effect on life, property and activities 4.3 obtain and use accurate information on the risk for the protection of others 4.4 produce a report on how best to minimise the risk to people, property and activities and recommend effective methods of implementation and control 4.5 identify routes and methods of implementation within a company to ensure that compliance with codes of practice and regulations pertaining to the risk are fully understood.

Guidance

Links

This unit may be linked with any unit that involves aspects of workplace practice and applications. If a holistic approach to the delivery of this unit is adopted, then its successful completion would enable learners to meet the Engineering Technician (Eng Tech) and Incorporated Engineer (IEng) requirements laid down in the UK Engineering Council Standard for Professional Engineering Competence (UK-SPEC) competence E2, ‘manage and apply safe systems of work’.

The unit can also be linked to the SEMTA National Occupational Standards in Engineering Management, particularly Unit 1: Develop and Maintain a Healthy and Safe Work Environment.

Essential requirements

Tutors delivering this unit will need to have an in-depth understanding of the health and safety management issues, legislation, procedures and documentation associated with their particular engineering industry.

Learners will need access to a real or realistic simulated environment, directly related to their engineering industry.

Employer engagement and vocational contexts

Liaison with employers can help provide suitable engineering environments. Visits to the learner’s workplace or other appropriate industrial facilities, will help foster employer cooperation and help set the focus for the delivery and assessment that have relevance and are of benefit to the whole cohort.

Unit 7: Business Management Techniques for Engineers

Unit code: R/601/1467

Level: 4

Credit value: 15

Aim

This unit investigates the functions, structures and inter-relationships of an engineering business. Learners will apply the skills of costing, financial planning and control associated with engineered products or services.

Unit abstract

In industry, engineers need to understand other factors which drive the business forward. The current financial state of the business will dictate what resources can be afforded to potential projects. Therefore, it is not always possible to select and use the latest technology. Most often, engineering solutions must also be business solutions which are constrained by budgets and time for example. To this end, engineering management requires understanding of business management techniques in order to advance business interests. This unit will provide the learner with the key knowledge and understanding of management skills required by engineering managers.

This unit is intended to give learners an appreciation of business organisations and the application of standard costing techniques, as well as an insight into the key functions underpinning financial planning and control. It also aims to expand learners' knowledge of managerial and supervisory techniques by introducing and applying the fundamental concepts of project planning and scheduling.

Learners will understand how to justify projects using financial tools such as profitability forecasts and contribution analysis. They will also be able to develop resource and project plans in the form of Gantt charts and with the use of software. They will be able to manage work activities using methods such as Just in Time (JIT) and Statistical Process Control (SPC).

Learning outcomes

On successful completion of this unit a learner will:

1 Know how to manage work activities to achieve organisational objectives

2 Be able to select and apply costing systems and techniques

3 Understand the key functions of financial planning and control

4 Be able to apply project planning and scheduling methods to an engineering project.

Unit content

1 **Know how to manage work activities to achieve organisational objectives**

Engineering business functions: organisational, management and operational structures in general engineering settings eg business planning, product/service development, design and production/delivery, quality assurance and control in relevant manufacturing, production, service or telecommunication industries

Processes and functions: business planning eg management, production/service planning, costing, financial planning; organisation eg mission, aims, objectives and culture

Manage work activities: product and service specifications and standards; quality, time and cost objectives eg just-in-time methods, value-added chains, statistical process control; working within organisational constraints and limitations

2 **Be able to select and apply costing systems and techniques**

Costing systems: systems eg job costing, process costing, contract costing; techniques eg absorption, marginal, activity-based

Business performance: measures and evaluation eg break-even point, safety margin, profitability forecast, contribution analysis, 'what if' analysis, limiting factors, scarce resources

3 **Understand the key functions of financial planning and control**

Financial planning process: short, medium and long-term plans; strategic plans; operational plans; financial objectives; organisational strategy

Factors influencing decisions: cash and working capital management eg credit control, pricing, cost reduction, expansion and contraction, company valuation, capital investment; budgetary planning eg fixed, flexible and zero-based systems, cost, allocation, revenue, capital, control, incremental budgeting

Deviations: variance calculations for sales and costs eg cash flow, causes of variance, budgetary slack, unrealistic target setting

4 **Be able to apply project planning and scheduling methods to an engineering project**

Project resources and requirements: human and physical resource planning techniques eg time and resource scheduling techniques, Gantt charts, critical-path analysis, computer software packages, work breakdown structure, precedence diagrams

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Know how to manage work activities to achieve organisational objectives	1.1 define engineering business functions 1.2 outline the inter-relationships between the different processes and functions of an engineering organisation 1.3 organise work activities to meet specifications and standards
LO2 Be able to select and apply costing systems and techniques	2.1 create appropriate costing systems and techniques for specific engineering business functions 2.2 measure the impact of changing activity levels on engineering business performance
LO3 Understand the key functions of financial planning and control	3.1 explain the financial planning process in an engineering business 3.2 examine the factors influencing the decision-making process during financial planning 3.3 analyse standard costing techniques
LO4 Be able to apply project planning and scheduling methods to an engineering project	4.1 establish the project resources and requirements 4.2 produce a plan with appropriate time-scales for completing the project 4.3 plan the human resource requirement and costs associated with each stage of the project.

Guidance

Links

This unit can be linked with *Unit 30: Quality Assurance and Management*.

Essential requirements

Learners will need access to manual records and relevant computer software packages to enable realistic project planning, resource allocation and costing assignments.

Employer engagement and vocational contexts

In estimating costs and approximating project completion times and human resource needs, it may be necessary to provide information from a 'given data source'. However, learners should be encouraged to research their own data requirements, ideally from local industrial attachments, work-placement or employer.

Unit 8: Engineering Design

Unit code: M/601/1475

Level: 5

Credit value: 15

Aim

This unit will enable learners to prepare an engineering design specification that meets customer requirements and produce a final design report.

Unit abstract

This unit will enable the learner to appreciate that design involves synthesising parameters that will affect the design solution. The learner will prepare a design specification against a customer's specific requirements. They will then prepare a design report that provides an analysis of possible design solutions, an evaluation of costs and an indication of how the proposed design meets the customer's specification. It is expected that the learner will, during the design processes, make full use of appropriate information and communication technology (ICT).

Learning outcomes

On successful completion of this unit a learner will:

1 Be able to prepare a design specification to meet customer requirements

2 Be able to analyse and evaluate possible design solutions and prepare a final design report

3 Understand how computer-based technology is used in the engineering design process.

Unit content

1 **Be able to prepare a design specification to meet customer requirements**

Customer requirements: all relevant details of customer requirements are identified and listed eg aesthetics, functions, performance, sustainability, cost, timing and production parameters; all relevant regulations, standards and guidelines are identified and listed eg international, national, company policy and procedures, industry specific, statutory bodies

Design parameters: implications of specification parameters and resource requirements are identified and matched; the level of risk associated with each significant parameter is established

Design information: all relevant information is extracted from appropriate reference sources; techniques and technologies used in similar products or processes are identified; use of new technologies are specified where appropriate; relevant standards and legislation are identified and applied throughout; design specification is checked against customer requirements

2 **Be able to analyse and evaluate possible design solutions and prepare a final design report**

Analysis of possible design solutions: selection and use of appropriate analysis techniques to achieve a design solution eg matrix analysis, brainstorming, mind mapping, forced decision making, simulation

Evaluation of conceptual designs: costs; future development potential; value engineering concepts

Compliance check: eg using checklists and/or design review procedures

Final design report: communicate rationale for adopting proposed solution; use of appropriate techniques and media in the presentation of the report eg sketches, charts, graphs, drawings, spreadsheets/databases, computer aided design (CAD), desk top publishing (DTP), word-processing

3 **Understand how computer-based technology is used in the engineering design process**

Key features of computer-aided design systems: 2D design and 3D modelling systems eg accessing standards, parts and material storage and retrieval, engineering calculations, PCB layouts, integrated circuit design, circuit and logic simulation (including ac, dc and transient analysis, schematic capture)

CAD software: accessing and using appropriate design software eg parts assembly, pipe-work and ducting layouts, networks, planned maintenance, scheduling, planning, stress and strain, heat transfer, vibration analysis, resource utilisation, plant layout, costing, circuit emulation, plant electrical services, for example, finite element analysis and printed-circuit board analysis software

Software evaluation: consideration of costs, compatibility and function

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Be able to prepare a design specification to meet customer requirements	1.1 establish customer requirements 1.2 present the major design parameters 1.3 obtain design information from appropriate sources and prepare a design specification 1.4 demonstrate that the design specification meets requirements
LO2 Be able to analyse and evaluate possible design solutions and prepare a final design report	2.1 produce an analysis of possible design solutions 2.2 produce and evaluate conceptual designs 2.3 select the optimum design solution 2.4 carry out a compliance check 2.5 produce a final design report
LO3 Understand how computer-based technology is used in the engineering design process	3.1 explain the key features of a computer-aided design system 3.2 use computer-aided design software to produce a design drawing or scheme 3.3 evaluate software that can assist the design process.

Guidance

Links

This unit can be linked with *Unit 2: Engineering Science* and *Unit 3: Project Design, Implementation and Evaluation*.

The unit can also be linked with the SEMTA Level 4 National Occupational Standards in Engineering Management, particularly Unit 4.12: Create Engineering Designs and Unit 4.13: Evaluate Engineering Designs.

Essential requirements

Access to suitable software packages will need to be available. These could include packages for computer-aided design, assembly procedures, critical path, plant layout, planned maintenance, utilisation, material selection, standard component and matrix analysis.

Employer engagement and vocational contexts

Delivery of this unit would benefit from visits to an engineering design facility or the attendance of guest speaker(s) with experience of engineering design in a relevant industrial environment.

Unit 9: Manufacturing Planning and Scheduling Principles

Unit code:	A/601/1480
Level:	5
Credit value:	15

Aim

This unit will develop learners' understanding of the methodologies and techniques that are used in process planning and scheduling and will enable them to plan and schedule a manufacturing activity.

Unit abstract

Learners will develop an understanding of how manufactured products and their associated processes are planned, monitored and controlled and extend their knowledge of and ability to apply both manual and computer-assisted methods and procedures. The unit covers process plans (for example forecasting, network analysis, etc), capacity assessment and scheduling. This leads the learner into inventory management with stock control and documentation systems. The last two outcomes require the learner to examine group technology, process plans and production scheduling.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand the use of process planning, capacity assessment and scheduling techniques

2 Understand inventory management including stock control, shop floor documentation systems and the functions of shop control

3 Understand the methods of classifying and coding component parts as key elements of group technology and their processing through grouped facilities

4 Be able to plan and schedule a manufacturing activity.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017 © Pearson Education Limited 2017

Unit content

1 **Understand the use of process planning, capacity assessment and scheduling techniques**

Process planning: forecasting; network analysis; critical path method (CPM); project evaluation and review technique (PERT); material requirement planning (MRP); equipment and tooling; make or buy decisions; computer aided-planning and estimating

Capacity assessment: bill of materials; economic batch size; assessment of load and capacity; effects of re-working and scrap; methods of increasing/decreasing capacity; time-phased capacity planning

Scheduling: lead times; critical path analysis (CPA); supplier and production schedules; Kanban; optimised production technology (OPT) philosophy; influence of scheduling on capacity planning dispatching; material requirement planning (MRP)

2 **Understand inventory management including stock control, shop floor documentation systems and the functions of shop control**

Inventory management: types of inventory; dependent and independent demand; role of buffer stock; cost of inventory

Stock control systems: periodic review; re-order points; two bin system; basic economic order quantities; Kanban

Documentation systems: works orders; routing document; job tickets; recording of finished quantities; re-work and scrap; stock records

Shop control: scheduled release of works orders; progressing; data collection and feedback

3 **Understand the methods of classifying and coding component parts as key elements of group technology and their processing through grouped facilities**

Classifying and coding: sequential; product; production; design; Opitz method; classification of parts into families

Grouped facilities: layout; product; process; fixed position; group; sequencing of families for groups of facilities

4 **Be able to plan and schedule a manufacturing activity**

Process plan: forecast to identify timings and completion dates; materials required; equipment and tooling required; methods or processes employed; labour requirements and planning for quality checks; proposal for data logging; use of computers; MRP

Production schedule: developed from the process planning and customer requirements; lead times; using scheduling techniques eg CPA, Gantt charts, software packages, OPT philosophy, MRP

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Understand the use of process planning, capacity assessment and scheduling techniques	1.1 evaluate the use of three different process planning techniques 1.2 select and assess the use of a capacity assessment technique for two different types of manufacturing process 1.3 explain the use of a range of scheduling techniques
LO2 Understand inventory management including stock control, shop floor documentation systems and the functions of shop control	2.1 explain an application of the principle of inventory management 2.2 compare and evaluate two different stock control systems 2.3 discuss two different shop floor documentation systems 2.4 explain the functions of shop control
LO3 Understand the methods of classifying and coding component parts as key elements of group technology and their processing through grouped facilities	3.1 explain the methods of classifying and coding component parts into family groups 3.2 explain how family groups of components are sequenced for processing through grouped facilities
LO4 Be able to plan and schedule a manufacturing activity	4.1 produce a process plan from a given set of data 4.2 produce a production schedule from a process plan.

Guidance

Links

This unit can be linked with *Unit 8: Engineering Design*, *Unit 10: Manufacturing Process* and *Unit 15: Design for Manufacture*.

The unit can also be linked to the SEMTA Level 4 National Occupational Standards in Engineering Management, particularly Unit 4.16: Schedule Activities for Engineering Methods and Procedures.

Essential requirements

Both manual records and relevant computer software of industrial standards will need to be available to enable realistic project and assignment work to be undertaken.

Employer engagement and vocational contexts

Liaison with industry should be encouraged in order to develop a valuable and relevant resource facility. Where possible, work-based experience should be used to provide practical examples of the planning and scheduling principles covered.

Unit 10: Manufacturing Process

Unit code: H/601/1487

Level: 4

Credit value: 15

Aim

This unit will develop learners' knowledge of manufacturing processes and techniques that can be applied to a range of materials for a variety of manufacturing applications.

Unit abstract

It is essential that engineering technicians involved in the planning, operation and management of manufacturing systems should have a broad underpinning knowledge of conventional production processes. Computer-aided processes are now the norm in medium- to large-scale manufacturing companies and are also to be found with small-scale specialist producers. The full potential of computer-aided systems cannot however be fully appreciated without knowledge of the conventional processes from which they are derived.

This unit provides learners with this knowledge of manufacturing processes and techniques. The first outcome gives an appreciation of conventional machining techniques together with associated tooling and work holding methods. The second outcome gives an appreciation of the basic moulding and shaping processes used with metals, plastics and ceramics. The final outcome covers non-conventional machining techniques that include electro-discharge machining, ultrasonic machining, etching of electronic printed circuit boards, laser-beam machining and plasma-jet machining.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand the use of conventional machining processes and techniques for generating geometrical forms for a given component specification

2 Understand the use of moulding and shaping processes for a given component specification

3 Understand the use of less conventional machining techniques for a given component specification.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017 © Pearson Education Limited 2017

Unit content

1 **Understand the use of conventional machining processes and techniques for generating geometrical forms for a given component specification**

Component manufacture: specify components for manufacture eg criteria-tolerances, types of material, machining technique, surface texture, material removal rates, speeds and feeds, cutting times, cutter offsets, table angles

Machining techniques: production of flat and cylindrical geometry eg milling, surface grinding, lapping, planing, turning, cylindrical grinding, centreless grinding, honing, super-finishing, thread milling techniques, jig boring, horizontal boring, vertical boring, transfer machines

Tooling requirements: multi-tooth cutting eg milling, grinding, hobbing, drilling, reaming, and broaching; single-point cutting eg turning, planing and slotting; appropriate cutting angles for given materials; types, advantages and disadvantages of coolants and cutting fluids used for various materials and processes eg advantages – prolonging tool life, increased material removal rate, improved surface finish; disadvantages – fumes and possible irritations to operators

Work-holding techniques: selection of appropriate work-holding devices eg three and four jaw chucks, vices, jigs, fixtures, clamping arrangements, vee blocks, angle plates and magnetic chucks; health and safety issues and limitations of devices

2 **Understand the use of moulding and shaping processes for a given component specification**

Component manufacture: specify components for moulding and shaping eg criteria-tolerances, type of moulding/shaping technique to be used, limitations of size, shape and production volume, properties of materials being moulded/shaped, surface texture, cost factors, post-moulding operations required (machining, clipping, welding, finishing)

Moulding processes: casting eg sand, die, investment and continuous casting; powder metallurgy; sintering

Shaping processes: extrusion eg direct, indirect and impact; forging eg drop, pressure and upset; rolling; hot and cold presswork eg forming, bending and deep drawing; metal spinning

Metallic materials: range applicable to component eg ferrous, non-ferrous, alloys

Ceramic materials: range applicable to component eg metallic carbides, nitrides and oxides

Material properties: changes to the molecular structure and hence the material properties that may arise from a moulding or shaping operation eg grain growth, work hardening, cracking, orientation of grain flow

Tooling requirements: appropriate tooling and equipment required to produce given components by moulding and shaping techniques eg re-usable moulds and non-permanent moulds, suitable casting materials for a particular casting process; press tools, punches, dies, press capacity and calculations in terms of tonnage

3 **Understand the use of less conventional machining techniques for a given component specification**

Component manufacture: principle of operation of the less-conventional machining techniques eg electro-discharge machining (EDM), wire erosion, ultrasonic machining, etching of electronic printed circuit boards (PCBs), laser-beam machining, plasma-jet machining; specification of components for less-conventional machining techniques eg criteria-tolerances, types of material, suitable technique, surface texture, material removal rate, cost factors

Tooling requirements: tooling and ancillary equipment needed to perform less-conventional machining techniques; work-holding techniques; health and safety issues

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Understand the use of conventional machining processes and techniques for generating geometrical forms for a given component specification	1.1 select suitable data and processes for component manufacture using a range of conventional machining techniques 1.2 assess tooling requirements and work-holding techniques for a given component using a range of conventional machining techniques
LO2 Understand the use of moulding and shaping processes for a given component specification	2.1 select suitable data and processes for component manufacture using moulding and shaping techniques for metals and ceramics 2.2 explain changes to material properties due to the moulding and shaping processes 2.3 explain the tooling requirements for producing a given component by moulding and shaping
LO3 Understand the use of less-conventional machining techniques for a given component specification	3.1 select suitable data and processes for component manufacture using a less-conventional machining process 3.2 explain the tooling and ancillary equipment requirements to manufacture a given component by a less-conventional machining process.

Guidance

Links

This unit can be linked with *Unit 15: Design for Manufacture* and *Unit 21: Materials Engineering*.

Essential requirements

There are no essential resources for this unit.

Employer engagement and vocational contexts

The learning outcomes and indicative content of this module lend themselves to be based on a real engineering environment. This approach would make the delivery more relevant through the use of detailed and realistic case study material. Equally, where learners have access to work-based traditional machining environments, including shaping and moulding, and less-traditional machining environments then they should be encouraged to use the real-life information available to them from this source wherever possible.

Unit 11: Supply Chain Management

Unit code:	K/601/1491
Level:	4
Credit value:	15

Aim

The aim of this unit is to examine the main principles, concepts and practices of supply chain management.

Unit abstract

This unit addresses the definition of a supply chain and supply chain planning, why it is important in any business, how the supply chain operates and the principles for supply chain improvement. Where appropriate, the global nature of the supply chain will be emphasised.

Learners will examine the components of supply chains and how these vary within different organisations. They will learn how organisations manage and control their supply chain functions to gain both competitive and cost advantage. They will also investigate supply chain planning from both the strategic and operational standpoint. They will identify and cost activities within supply chain operations, referring to performance indicators, marketing, response to customer needs and benchmarking.

As there is always a need to improve supply chain performance, learners will investigate methods used to enhance systems, approaches to performance improvement and the role of technology in supply chain improvement.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand the strengths, weaknesses and competitive advantage of supply chains

2 Understand the use of supply chain planning

3 Be able to analyse an organisation's supply chain operation

4 Be able to evaluate a supply chain, determine an optimum supply chain solution and prepare an implementation plan.

Unit content

1 **Understand the strengths, weaknesses and competitive advantage of supply chains**

Supply chain: what is meant by a supply chain; main components; variation within different organisations; importance of harmonising physical and information flows within a supply chain in an integrated manner; types of supply chain flow and direction; how organisations can manage and control their supply chain to gain competitive and/or cost advantages; why supply chains may not always function in an effective way eg Forrester or bullwhip effect, uncertainty in delivery, large amount of stock, lack of forward planning

2 **Understand the use of supply chain planning**

Supply chain planning: planning a supply chain from a strategic and operational standpoint; tactical plans; relationship between supply chain planning and customer service levels; role of inventory and the increasing need for effective inventory management in the supply chain; available supply chain alternatives eg outsourcing, contracting relationships, joint ventures, wholly owned subsidiaries; their characteristics and constraints; process involved in new and developing supply chain strategies; relationship with company objectives

Key elements: key elements involved in the supply chain eg location of suppliers, main processes carried out, relationships between each part of the supply chain, integration of parts of the supply chain

3 **Be able to analyse an organisation's supply chain operation**

Supply chain operations: identifying and costing the separate activities within a supply chain; types and role of performance indicators in supply chain management; why an effective supply chain can operate as part of the marketing mix of an organisation; how and why supply chains respond to customer needs; the nature and use of benchmarking

4 **Be able to evaluate a supply chain, determine an optimum supply chain solution and prepare an implementation plan**

Supply chain improvement: ways in which supply chain performance can be enhanced towards lean and agile systems; principal trade-offs involved in supply chain management; different approaches to performance improvement; role of information processing systems in supply chain improvement; supply chain audit characteristics of an optimum supply chain solution; improvement implementation plan

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Understand the strengths, weaknesses and competitive advantage of supply chains	1.1 outline and explain three supply chains for an organisation and make comparisons with similar and dissimilar types of organisation 1.2 analyse the differences between the types and directions of flows in a supply chain 1.3 evaluate the main strengths and weaknesses of an organisation's supply chain and the extent to which it provides competitive advantage for the business
LO2 Understand the use of supply chain planning	2.1 explain how company objectives are translated into a meaningful supply chain strategy 2.2 analyse the pattern and requirements for inventory in an organisation's supply chain 2.3 devise suitable alternative supply chain solutions including outsourcing potential 2.4 describe the importance of the key elements of the supply chain
LO3 Be able to analyse an organisation's supply chain operation	3.1 prepare a cost report on the various activities within the supply chain operation 3.2 measure the performance of an organisation's supply chain 3.3 benchmark supply chain performance against that of similar organisations 3.4 evaluate the suitability of benchmarks for use against company objectives
LO4 Be able to evaluate a supply chain, determine an optimum supply chain solution and prepare an implementation plan	4.1 conduct and evaluate a supply chain audit 4.2 analyse the different trade-offs involved in a supply chain 4.3 determine an optimum supply chain solution 4.4 devise a suitable implementation plan.

Guidance

Links

This unit links with *Unit 23: Engineering Procurement*, *Unit 34: Integrated Logistical Support Management* and *Unit 12: Material Handling Systems*.

Essential requirements

There are no essential resources for this unit.

Employer engagement and vocational contexts

Liaison with industry should be encouraged in order to develop a valuable, relevant and alternative resource facility.

Unit 12: Material Handling Systems

Unit code: F/601/1495

Level: 4

Credit value: 15

Aim

The aim of this unit is to familiarise learners with the knowledge and skills required in the management of materials in the engineering/manufacturing industries.

Unit abstract

Learning outcome 1 introduces learners to the aims and strategies of material handling systems. This is followed in learning outcome 2 by a detailed study and evaluation of systems. Learning outcome 3 examines the control of material handling whilst the learning outcome 4 covers the planning and layout of material flow and handling systems.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand the aims of logistics and strategies for achieving these aims

2 Understand about the operation of material handling systems

3 Understand the control of material handling systems

4 Be able to plan the layout of a material handling system.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017

Unit content

1 **Understand the aims and strategies used for logistics**

Aims of logistics: flow of materials; movement of work in progress; minimising cost of holding stock and maintaining high quality

Strategies used: eliminate handling or movement; combine processing and movement; plan layout of operation together with planning of material handling; use automation or mechanical handling; use of correct equipment; training; minimise pick up/put down movements; use unit loads, pallets and or containers to avoid mixing materials; economy of movement; central authority and control of operation

2 **Understand the operation of material handling systems**

Stages of engineering material handling: selection and loading; moving and unloading; placement and positioning; materials can be raw materials, components, sub assemblies, parts, tools and consumables

Criteria for the selection of a material handling system: location of material centres; material type and appropriate handling conditions; capital and resources available; future needs – expansion or contraction of operation; total cost of the handling system; compatibility with existing equipment and systems technologies

Material handling systems: comparison of a centrally co-ordinated and controlled operation with one that is controlled by individual departments; comparison of automated systems with semi-automated systems

Cost benefit analysis: benefits eg reduced accidents and losses, increased capacity, speed, space, flexibility, ‘double handling’ bottlenecks and accidents, cost of designing, installing, staffing and maintaining

3 **Understand the control of material handling systems**

Control of material flow: computer-controlled networks; programmable logic controllers (PLCs); dedicated software; departmental control panels; automated storage and retrieval systems (ASRs); robots; radio-controlled vehicles; closed circuit TV; advanced guided vehicles (AGVs) with onboard computers

Tracking and identification: voice recognition; coding systems; job tickets; programmable silicon micro chips; recording devices such as bar code reader (OCR); numbers input manually; identification devices such as optical sensors; proximity sensors

Controlled material handling system: using material flow process, dedicated or non-specialist material handling programmes to represent the control of a material handling system; detailed critical analysis of all decisions made; detail all critical control points; critical path network diagrams; variety of graphical communication techniques

4 **Be able to plan the layout of a material handling operation**

Types of material handling equipment: cranes; lifts; vehicles; conveyors; pneumatic and hydraulic equipment; towing; chute and robots

Application: the range of equipment eg overhead, vertical, horizontal, horizontal fixed route, horizontal non-fixed route; speed of the equipment

Factors influencing selection: material handling equipment; materials features; size; weight; nature; volume/rate of movement; route of movement; storage before and after movement; safety/hazards and concurrent processing

Planning the layout: features of modern material handling systems; detailed analysis of material movement needs; work study and layout and planning techniques; handling conditions required by the materials; requirements and constraints of the material handling system; critical path analysis techniques and Gantt charts to determine the key processes, procedures, sequence of events, equipment and time requirements; technical and graphical techniques to illustrate the final layout

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can**:
LO1 Understand the aims and strategies used for logistics	1.1 identify the aims of logistics for material handling 1.2 explain strategies used for achieving the aims of logistics
LO2 Understand the operation of material handling systems	2.1 describe the stages of engineering material handling 2.2 explain the criteria used for the selection of a material handling system 2.3 compare different material handling systems 2.4 carry out a cost benefit analysis by comparing two modern material handling systems
LO3 Understand the control of material handling systems	3.1 explain the systems used for the control of material flow 3.2 explain material tracking and identification methods 3.3 evaluate a controlled material handling system using a range of techniques
LO4 Be able to plan the layout of a material handling operation	4.1 identify modern material handling equipment and its application 4.2 identify and analyse the movements, conditions, requirements and constraints of a proposed material handling system 4.3 justify the selection of material handling equipment for the system 4.4 use critical path analysis to plan the material handling operation 4.5 present a layout of the proposed system using appropriate graphical techniques.

Guidance

Links

This unit can be linked with *Unit 11: Supply Chain Management* and *Unit 34: Integrated Logistical Support Management*.

Essential requirements

Learning outcomes 3 and 4 require the use of either detailed case study information and/or primary information obtained from research and industrial visits.

Employer engagement and vocational contexts

Visits to local manufacturers can help provide relevant and up-to-date information. Many multinational companies are large enough to accommodate in-house educational officers, who will tailor visits according to specific requirements.

Unit 13: Application of Machine Tools

Unit code:	Y/601/1499
Level:	4
Credit value:	15

Aim

This unit will develop the skills and understanding needed for the safe and efficient production of components on manual machine tools.

Unit abstract

This unit introduces learners to the types of manually operated machine tools commonly used in industry and typical applications of such equipment. It introduces the theory of cutting tools, the practice of tool and work setting for production on manual machine tools and the checking of critical features and dimensions against specifications. Safe use of equipment will be a continuing theme throughout the unit.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand the characteristics of a range of machine tools

2 Understand machining operations

3 Understand material removal and forming principles

4 Be able to produce components to specification using safe working practices.

Unit content

1 **Understand the characteristics of a range of machine tools**

Machine tools: a range of machine tools and their applications eg centre lathes, vertical and horizontal milling machines, cylindrical and surface grinders, centreless grinders, lapping, honing, planing and shaping machines, internal and external broaching machines, sawing machines, presses, sheet and tube bending machines; types of drives eg for lathes, milling machines and presses; relative motion between cutting tool and workpiece

Work holding techniques: the six degrees of freedom of a rigid body with respect to work holding and jig and fixture design eg the need for rigidity in design and build of machine tools, three and four-jaw chucks, use of centres, machine vices, worktable clamps, magnetic tables

Tool holding: toolposts; Morse taper shanks; Jacobs chucks; milling machine arbors; mounting and dressing of grinding wheels

2 **Understand machining operations**

Components and geometries: component features typically associated with lathe work, milling, sheet metal forming and broaching eg:

Lathe work:	rotational operations – diameters and face turning, taper turning, chamfers, radii, drilled holes and internal bores, deep holes, internal and external threads, grooving, knurling, parting off, roughing and finishing cuts, the purpose and use of cutting fluids
Milling:	prismatic operations – face milling, slab milling, profiles, pockets and slots, drilling, reaming, thread tapping, thread milling, counter-boring, counter-sinking, roughing and finishing cuts
Press work:	sheet metal forming operations – blanking, piercing, drawing, bending, notching, cropping, use of progression tooling, finishing operations
Broaching:	internal and external – square and round holes, splines, gear teeth, keyways, rifling and flat, round and irregular external surfaces

3 **Understand material removal and forming principles**

Tooling: choice and effects of tool geometries; choice of tool material; permissible depth of cut; types and consequences of tool wear; importance of clearance in press-working operations; calculation of expected tool life

Forces: theory of metal cutting; mechanics of chip formation; shearing mechanisms in press work; calculation of forces exerted on cutting/forming tool and workpiece during various operations; calculation of power required to perform specific operations; use of dynamometers and other condition monitoring/measuring equipment

Speeds and feeds: calculation of speeds and feeds for turning and milling operations on a variety of workpiece features, sizes and materials (eg aluminium alloys, mild steel, tool steels, cast metals and alloys); relationship between cutting speed and tool life – economics of metal removal

4 **Be able to produce components to specification using safe working practices**

Health and safety: issues related to machine tools, workshops and the production environment in general; responsibilities of the employer and employee under the Health and Safety at Work Act and other legislation; correct and approved use and operation of systems and equipment; potential hazards for given machine tools

Principles of production: tool and work setting techniques; interpretation of specifications and engineering/production drawings; feature measurement eg depths, diameters, screw threads

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can**:
LO1 Understand the characteristics of a range of machine tools	1.1 explain the typical axis conventions of given machine tools 1.2 explain the operation of types of drive and the axis control systems, such as hand-wheels and servo-motors, for given machine tools 1.3 describe the six degrees of freedom of a rigid body and how they relate to work holding techniques 1.4 describe work and tool holding devices for given machine tools
LO2 Understand machining operations	2.1 assess the suitability of machine tool types for the production of specific components and geometries 2.2 plan the sequence of operations required to produce specific components 2.3 describe the machining and forming processes involved in the production of specific features
LO3 Understand material removal and forming principles	3.1 select appropriate tooling for the production of specific features on specific materials 3.2 determine the forces acting on the tool face and work piece during ideal orthogonal cutting 3.3 calculate speeds and feeds for turning and milling operations for a variety of tool and work piece materials 3.4 describe the mechanisms and effects of different types of tool wear and catastrophic failure 3.5 estimate the life of given tools for specific applications
LO4 Be able to produce components to specification using safe working practices	4.1 demonstrate awareness of health and safety issues related to the specific machine tools used and the workshop in general 4.2 select correct tooling and machine settings 4.3 produce given components to specification in compliance with the planned sequence of operations.

Guidance

Links

This unit can be linked with *Unit 10: Manufacturing Process*.

Essential requirements

Learners will need to have access to appropriate machine tools and properly trained support staff.

Employer engagement and vocational contexts

Delivery would benefit from visits to local engineering companies that use a wide range of machine tools and from visits from guest speakers with industrial experience of machining operations.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017

Unit 14: Computer-aided Machining

Unit code: J/601/1501

Level: 4

Credit value: 15

Aim

This unit will develop learners' understanding of computer-aided machining (CAM) systems and the related skills found in manufacturing and engineering companies.

Unit abstract

It is essential that engineering technicians involved in the planning, operation and management of manufacturing systems should have a broad underpinning knowledge of computer-aided machining processes. The first learning outcome focuses on the hardware and software of CAM systems. The second and third learning outcomes deal with manual and computer-assisted part programming, giving learners the opportunity to derive and prove part-programs for engineered components. The final outcome is concerned with quality control in CAM systems, particularly the various levels of inspection and the capture, transmission and analysis of quality control data. It is intended that the learner will gain both a detailed knowledge of programming methods and the practical skills necessary for programming industry standard CAM systems.

Due to the rapid growth in this area of technology it is expected that delivery centres may need to review and update aspects of the indicative content of the unit as required to keep pace with and also meet the needs of their local industries.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand the operational characteristics of CAM systems

2 Be able to produce and prove manual part programs

3 Be able to produce and prove computer-assisted part programs

4 Understand inspection and quality control in CAM systems.

Unit content

1 **Understand the operational characteristics of CAM systems**

Hardware elements: computer eg mainframe, mini, micro; computer power and memory; printer; mouse; digitiser; digital and screen data displays; disc drives; axes of CNC machines; parametric settings eg zero datum setting and transfer, manual modes, program overrides

Software elements: operating system; CAM software; CAM database management systems; program editing facilities; diagnostic testing techniques

Inputs: geometry data; material specifications; CAD data

Outputs: manufacturing data; tool data; cutter path; component profile; CAM file

Component location, *work-piece clamping and tool holding*: methods eg jigging devices, holding techniques, punch tooling, formers for bending

2 **Be able to produce and prove manual part programs**

Elements and structures: investigation of system initialisation; tooling information and data; positional control and sequence

ISO standards: use of blocks, word and letter addresses; system management; positional data and coded data transfer

Programming techniques: macro routines; sub-routines; rotation; zero shifts; scaling and minor imaging

3 **Be able to produce and prove computer-assisted part programs**

Functions: generation of graphics eg use of third party software in design or draughting mode (EdgeCam, SmartCam); component profile definition eg simple 2D profile with internal circular and square pockets and holes on a pitch circle diameter suitable for fixed/canned cycle manipulation; geometry manipulation; tooling and machinery sequences; cutter path simulation; post-processing

Databases: CAD profile and attribute data; material files; tool data; cutter location files; report generators; Bill of Materials (BOM)

Macro routines: macro routines eg continuous operations, automatic tooling sequences, standard components

4 **Understand inspection and quality control in CAM systems**

Levels of inspection: inspection eg tooling verification, datum and location checks, in-process measurement, post-process inspection, qualitative data and attributes, statistical analysis, technical and management information

Data capture: tactile sensing; non-tactile sensing; data transmission features

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Understand the operational characteristics of CAM systems	1.1 explain the function of the hardware and software elements of a CAM system 1.2 identify the inputs and outputs of a CAM system 1.3 explain the methods of component location, clamping and tool holding in CNC machines
LO2 Be able to produce and prove manual part programs	2.1 utilise elements and structures of a CNC part program when producing and proving a manual part program 2.2 use appropriate ISO standards with respect to codes and program format when producing and proving a manual part program 2.3 use programming techniques to promote enhanced system performance 2.4 produce manually written part programs for engineered components 2.5 input manually written part programs to a CNC machine and prove their accuracy
LO3 Be able to produce and prove computer-assisted part programs	3.1 use an appropriate range of functions when producing and proving computer-assisted part programs 3.2 use a database in support of computer-assisted part programming 3.3 use macro routines in support of computer-assisted part programming 3.4 produce computer-assisted part programs for engineered components 3.5 pass computer-assisted part programs to a CNC machine and prove their accuracy
LO4 Understand inspection and quality control in CAM systems	4.1 review the various levels of inspection in CAM systems 4.2 assess the techniques used for data capture in automated inspection systems 4.3 explain the significance of adaptive control methods in CAM systems.

Guidance

Links

This unit may be linked with *Unit 22: Programmable Logic Controllers*.

Essential requirements

Centres delivering this unit will need to have access to industrial-standard CNC machining centres and programming hardware and software.

Employer engagement and vocational contexts

Visits to industrial installations will be of value to supplement learning activities and provide learners with a wider appreciation of the range of possible CAM applications.

Unit 15: Design for Manufacture

Unit code:	R/601/1503
Level:	5
Credit value:	15

Aim

This unit will develop learners' understanding of the processes involved in analysing a product design and preparing for its manufacture.

Unit abstract

The learner will identify the key factors that need to be considered in the design of a product for manufacture. This will include the selection of the most economic methods for manufacture and assembly, and the importance of specified tolerances and dimensions for products and components. The unit also looks at the applications of computer-based technologies used in design for manufacture.

The unit can be delivered effectively through case studies and industrial visits that reinforce the relevance and provide context and scale. However, it would also be very effective with work-based learners where the focus of assessment could be directed towards products and components from the learner's industry/workplace. The unit has also been designed to be non-sector specific and therefore could be used in a range of industry settings.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand how to analyse a product design for its economic manufacture

2 Understand the product design features and techniques that facilitate economic assembly

3 Be able to apply the principles of geometrical tolerancing

4 Be able to select and use appropriate computer-aided manufacturing software.

Unit content

1 **Understand how to analyse a product design for its economic manufacture**

Manufacturing methods: key design factors eg design form, material type and properties, quality requirements, manufacturing equipment, processing capability, costs, skills of labour force, impact on environment; analytical review of manufacturing methods eg alternatives, most suitable, least waste, use of design criteria; decision-making eg which, why, alternatives, suitability

Total cost: breakdown of the three major costs eg material, labour and overheads; fixed and variable costs; relationship between manufacturing method and complexity of design eg form, finish and relative costs; break-even analysis

Standardisation: standards relevant to design form and materials eg BS, ISO, industry-specific; use of standard components, parts and fittings; application of preferred number methods for detection and standardisation; advantages of using standard parts eg design, development, tooling, planning, choice, labour, ease of replacement; inter-changeability, cost; conformity with relevant health and safety standards

Process requirements: factors affecting material requirements eg form, size, weight, quality, processing method, quantity, availability, service life, and mechanical, electrical and chemical characteristics

Implementation: timescale, ease of implementation, lifespan/upgradeability

2 **Understand the product design features and techniques that facilitate economic assembly**

Methods of assembly: application of analytical and questioning techniques to select the most appropriate method of assembly eg a value engineering approach that evaluates the specification and validity of the product; cost saving techniques eg variations between similar components, sequencing of assembly stages, symmetrical and asymmetrical parts, number of components

Economic manufacture: automated methods eg ability to feed and assemble components automatically, unidirectional component location, ease of handling, positioning, stacking and accessibility within assemblies; significant features of good design eg location of spigots, flanges, tenons, locating faces, accessibility, alignment, families of parts or groupings

3 **Be able to apply the principles of geometrical tolerancing**

Principles of geometric tolerancing: applications of dimensional tolerance and the dimensioning of components, sub-assemblies and assemblies, using relevant BS and ISO standards; effects of tolerance build-up and assess its application on an assembled product; dimensional data for the manufacture and inspection of a component

4 **Be able to select and use appropriate computer-aided manufacturing software**

Manufacturing software: selection and use of computer numerical control (CNC) software for component manufacturing; selection and use of computer-aided manufacturing software (CAM) for product assembly and material selection/handling

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Understand how to analyse a product design for its economic manufacture	1.1 examine the most appropriate manufacturing methods for a product 1.2 discuss the elements involved in the total cost of a product 1.3 explain the advantages and disadvantages of standardisation 1.4 analyse the manufacturing process and material requirements for a component
LO2 Understand the product design features and techniques that facilitate economic assembly	2.1 explain the most appropriate method of assembly for a product 2.2 explain the flexible manufacturing systems and robots used in the economic manufacture of a product 2.3 evaluate the features of a component that assist and/or prevent economic manufacture using automatic assembly methods
LO3 Be able to apply the principles of geometrical tolerancing	3.1 apply the principles of geometric tolerancing to the manufacture of a product 3.2 report on the effects of tolerance build-up and assess its application on an assembled product 3.3 select and use dimensional data for the manufacture and inspection of a component
LO4 Be able to select and use appropriate computer-aided manufacturing software	4.1 demonstrate how CNC software can be used for component manufacture 4.2 demonstrate how CAM software programs can be used for the assembly of a product 4.3 demonstrate how CAM software can be used for material selection and handling processes.

Guidance

Links

This unit can be delivered on a stand-alone basis but does require the learner to have an understanding of the processes of engineering design and manufacture. For example *Unit 2: Engineering Science*, *Unit 8: Engineering Design* and *Unit 10: Manufacturing Process* would provide a suitable foundation of study.

The unit can also be linked with the SEMTA Level 4 National Occupational Standards in Engineering Management, particularly Unit 4.12: Create Engineering Designs.

Essential requirements

Centres will need to provide access to suitable manufacturing facilities, CAD/CAM and appropriate software packages.

Employer engagement and vocational contexts

The unit would benefit from input by guest speakers from industry and visits to a facility using flexible manufacturing systems including the use of CNC and CAM software applications.

Unit 16: Advanced Manufacturing Technologies

Unit code:	D/601/1505
Level:	5
Credit value:	15

Aim

This unit develops learners' understanding of advanced manufacturing technologies and the safety and technical requirements of producing goods economically.

Unit abstract

In a competitive market, companies aim to produce products of the highest quality at the lowest cost in order to maximise profitability. Companies employ engineers to identify the most efficient equipment and processes necessary to achieve this. This can best be achieved when engineers have a broad knowledge and experience of the technologies that are available.

There have been major advances in manufacturing techniques both in terms of plant and processes. Information and communication technology (ICT) and computer-aided design and computer-aided manufacture (CAD/CAM) technologies are used widely in the machinery used to produce parts. There has also been much analysis of how people and plant interact in production to optimise effectiveness in terms of Kanban and work-flow systems.

This unit introduces advanced manufacturing technologies and the safety and technical requirements of producing goods economically. The function, purpose and economic evaluation of different manufacturing technologies and strategies are investigated. Manufacturing options for single piece, small, medium and large batch production are considered. Flow line production is considered as well as non-traditional and emerging technologies. Specialised machining technologies such as electro-discharge and ultrasonic machining are also examined.

Learners will achieve an understanding of key issues in implementing suitable strategies and adopting suitable advanced technologies.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand health and safety requirements in the manufacturing workplace

2 Understand the function and purpose of existing Advanced Manufacturing Technology (AMT) installations

3 Be able to analyse benefits and drawbacks to building flexibility into the manufacturing process

4 Know the applications of special manufacturing processes.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017 © Pearson Education Limited 2017

Unit content

1 **Understand health and safety requirements in the manufacturing workplace**

Health and safety within the company: organisation levels; people involved; responsibilities of the employer and individual employees; appointment and role of safety representatives and safety officers; safety inspection procedures and legal requirements

Safety in automated areas: guarding of unmanned equipment and areas; safety in the design of a flexible manufacturing cell (FMC) and a flexible manufacturing system (FMS)

2 **Understand the function and purpose of existing Advanced Manufacturing Technology (AMT) installations**

AMT installations: CNC turning centres; multi-head/turret machines; sliding head and single/multi spindle autos; gantry loading machines; industrial robots for materials handling and assembly operations; CNC machining centres, multi-pallet systems; CNC mill-turn centres – C axis turning, Y axis lathes; live tooling; automatic tool change systems for milling and turning; probe systems for work and tool setting (spindle and bed mounted probes, turret mounted probes); adaptive control system; block tooling and replacement sister tooling; part programming for multiple fixtures

Manufacturing strategies: high volume production techniques; transistor lines; flexible transfer lines; group technology (GT); FMS; FMC; low-volume and small, medium and large-batch production techniques; one-off and prototype production

3 **Be able to analyse benefits and drawbacks to building flexibility into the manufacturing process**

Benefits and drawbacks: economics of machining; economic batch sizes; break-even charts; costs of setting; operating; training; maintenance; machine specifications; hardware and software specification; cost of software/hardware upgrades; assessment of 'intangible' and 'unquantifiable' benefits; calculation of cycle times; CAM layouts for autos

4 **Know the applications of special manufacturing processes**

Manufacturing processes: chemical machining; electro discharge machining (die sinking, wire cutting); laser machining; water jet cutting; PCB routing and drilling; ultrasonic machining; rapid prototyping; flame cutting; plasma cutting; emerging technologies; economics of non-traditional manufacturing processes

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Understand health and safety requirements in the manufacturing workplace	1.1 explain how health and safety is catered for within an organisation 1.2 assess the legal requirements and procedures for health and safety inspections 1.3 discuss the safety requirements and features which should be included in the design of automated areas
LO2 Understand the function and purpose of existing Advanced Manufacturing Technology (AMT) installations	2.1 review the use of a range of Advanced Manufacturing Technology (AMT) installations 2.2 evaluate the benefits of different manufacturing strategies
LO3 Be able to analyse benefits and drawbacks to building flexibility into the manufacturing process	3.1 calculate break-even points and identify suitable processes for given quantities 3.2 calculate cycle times for given components using specified equipment 3.3 specify CAM layouts for single spindle autos 3.4 make decisions based on the initial costs and running costs of Flexible Manufacturing Systems (FMS), Flexible Manufacturing Cells (FMC) and stand-alone machinery
LO4 Understand the applications of special manufacturing processes	4.1 explain the technical requirements, uses and applications of special manufacturing processes 4.2 discuss the benefits and drawbacks of special manufacturing processes 4.3 identify the mix of manufacturing process equipment required to produce given components and assemblies economically.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017

Guidance

Links

This unit may be linked with *Unit 13: Application of Machine Tools*, *Unit 18: Advanced Machine Tools* and *Unit 31: Value Management*.

Essential requirements

Learners will need access to a range of advanced manufacturing technology installations.

Employer engagement and vocational contexts

Centres should try to work closely with industrial organisations in order to bring realism and relevance to the unit. Industrial visits to view existing production facilities would be of great advantage.

Unit 17: Business Improvement Techniques

Unit code: Y/601/1535

Level: 5

Credit value: 15

Aim

This unit will provide learners with knowledge of some of the business improvement methodologies and techniques that can be applied in a variety of manufacturing situations.

Unit abstract

This unit will enable learners to apply the principles of lead-time analysis by using a range of processes associated with this. They will also be able to use techniques to reduce set-up times for a particular application and present this improvement as a standard operating procedure. Learners will be able to describe the techniques employed in total productive maintenance (TPM) and explain the benefits. They will also be able to investigate and discover where the use of optimised production technology (OPT) is useful to make whole factory or whole manufacturing/business unit improvements.

Learning outcomes

On successful completion of this unit a learner will:

1 Be able to apply the principles of lead-time analysis by creating a lead-time profile, frequency diagram and by using a cause and effect diagram

2 Be able to use techniques in set-up reduction and prepare an improved standard operating procedure

3 Understand the benefits of total productive maintenance (TPM) techniques

4 Understand optimised production technology (OPT).

Unit content

1 **Be able to apply the principles of lead-time analysis by creating a lead-time profile, frequency diagram and by using a cause and effect diagram**

Lead-time profiles: representative parts or processes; improvements to profiles; planning improvements; problem solving and route cause analysis eg Ishikawa diagram, fishbone diagram, cause and effect diagram with addition of cards (CEDAC)

Principles and processes: objectives and targets for reduction in lead-time; identifying lead-time profiles with problems; improvement opportunities eg supply or delivery of parts, improved work flow, improved quality, flexibility of people, launch of material, inventory balance; determination of waste; frequency diagrams; identifying bottlenecks or constraints within lead-time profiles

2 **Be able to use techniques in set-up reduction and prepare an improved standard operating procedure**

Reduction activity techniques: evaluating improvement ideas; distinguishing between internal and external activities with reference to set-up; route cause analysis; principles and application of the 5 why's

Standard operating procedure: all of the new steps and time required for each step; differentiation between internal and external steps; standard equipment and its location eg cutting tools, clamps, inspection equipment; information required for a quick set-up and its location eg CNC programmes, drawings, manufacturing instructions

3 **Understand the benefits of total productive maintenance (TPM) techniques**

TPM techniques: obtaining information; how to select a resource eg plant, equipment, machines, office equipment, services equipment, utilities; seven steps of autonomous and planned maintenance; overall equipment effectiveness; standard operating procedures

Scope of TPM: resources eg plant, equipment, machines, office equipment, services equipment, utilities; countermeasures for chronic and sporadic loss; benefits of TPM

4 **Understand optimised production technology (OPT)**

Principles of OPT: balancing flow (not capacity); determination of non-bottleneck utilisation; critical and non-critical resources; activation of resources; throughput and inventory governed by bottlenecks; transfer batch

Throughput accounting: contribution per factory or unit hour; total factory or unit cost per hour; return per factory or unit hour; recommendations for improvements to meet the aims of OPT

Aims of OPT: increasing plant throughput; decreasing inventory; decreasing operating expenses

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Be able to apply the principles of lead-time analysis by creating a lead-time profile, frequency diagram and by using a cause and effect diagram	1.1 gather information and create lead-time profiles 1.2 produce a frequency diagram listing the major bottlenecks or constraints as identified by lead-time profiles 1.3 use a cause and effect diagram to identify improvement opportunities and determine waste
LO2 Be able to use techniques in set-up reduction and prepare an improved standard operating procedure	2.1 carry out a set-up reduction activity on a chosen machine, or process using the appropriate techniques 2.2 produce standard operating procedures for a new set-up
LO3 Understand the benefits of total productive maintenance (TPM) techniques	3.1 evaluate a range of techniques used in TPM 3.2 identify the countermeasures for chronic and sporadic loss and explain the scope of TPM
LO4 Understand optimised production technology (OPT)	4.1 explain the importance of the principles of OPT to the aims of OPT 4.2 use throughput accounting to measure the performance of a factory or unit 4.3 make recommendations for improvements to meet the aims of OPT.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017 © Pearson Education Limited 2017

Guidance

Links

This unit is designed to stand alone but has links with *Unit 9: Manufacturing Planning and Scheduling Principles* and *Unit 20: Quality and Business Improvement*.

This unit can be linked with the SEMTA Level 4 National Occupational Standards in Business Improvement Techniques, particularly:

- Unit 8: Carrying Out Lead Time Analysis
- Unit 11: Applying Set-up Reduction Techniques
- Unit 12: Applying Total Productive Maintenance (TPM)
- Unit 36: Creating Standard Operating Procedures.

Essential requirements

A range of financial and other performance data is required to enable accounting measures to be calculated and used. Both manual records and relevant computer software, of industrial standard, will also need to be available to enable realistic project work to be undertaken.

Employer engagement and vocational contexts

Liaison with industry should be encouraged in order to develop a valuable, relevant and alternative resource facility.

Unit 18: Advanced Machine Tools

Unit code:	M/601/1539
Level:	5
Credit value:	15

Aim

This unit introduces the theory of safe and efficient production of components on computer numeric control (CNC) machine tools. It also provides a broad knowledge about automated and flexible manufacturing.

Unit abstract

This unit introduces learners to the types of CNC machine tools commonly used in industry and typical applications of such equipment. Learners will develop an understanding of the design and build of advanced machine tools and the economics of production on CNC plant. The concept of cellular manufacture is introduced and is supported by the programming of programmable logic controllers (PLCs). Workholding and tooling issues for CNC are covered and reference is made to the special needs of high-speed machining. The application of probes for work and tool setting is discussed. Safe use of equipment will be a constant theme throughout the unit.

The unit is intended to lead the learner towards an understanding of machine tool technology and its utilisation through the study of theory and practical application.

Learning outcomes

On successful completion of this unit a learner will:

1 Be able to determine the cost of producing simple components on CNC equipment

2 Understand the design and construction of CNC machine tools

3 Understand the use of tool management in automated environments

4 Understand the requirements of a flexible manufacturing cell (FMC) and the uses of programmable logic controllers (PLCs).

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017 © Pearson Education Limited 2017

Unit content

1 **Be able to determine the cost of producing simple components on CNC equipment**

Economics of production on CNC equipment: advantages and disadvantages of CNC; comparison of CNC and manual machine tools eg impacts on productivity, quality and flexibility; comparison of costs of simple components produced manually and by CNC; determination of cost of producing specific components on CNC machine tools based on machine utilisation; hourly machine rates, labour rates and other overheads

2 **Understand the design and construction of CNC machine tools**

Design and construction of CNC machine tools: history of machine tools; axis conventions; horizontal and vertical lathes; horizontal and vertical milling machines; multi-axis machine tools – 4, 5, and 6 axis milling machines and machining centres, 3 and 4 axis turning centres and millturn centres; special considerations for high speed machining; special purpose machine tools; cast versus fabricated bases; modular designs; typical configurations; requirement of machine tools – rigidity, power requirements, cost of construction

Control systems: relationship between CNC controller and machine control unit (MCU); closed-loop control and feedback systems; types of positional encoders

3 **Understand the use of tool management in automated environments**

Tool management in automated environments: tool libraries; data requirements; geometry and offsets; feeds and speeds; control of maximum depth of cut; updating; linking tool libraries with bill of materials (BOM)

Tool life management: sister tooling; adaptive control for tool wear monitoring; probing systems for tool setting and tool wear detection; tool wear compensation by workpiece probing

Tool delivery: tool pre-setting and storage; automated tool stores; automated tool delivery and loading

4 **Understand the requirements of a flexible manufacturing cell (FMC) and the uses of programmable logic controllers (PLCs)**

Flexible manufacturing: requirements of FMCs (group technology (GT) and just-in-time (JIT) manufacturing); typical cell configurations

Automated materials handling: use of robots for machine loading/unloading; multi-pallet systems for milling; bar feeding systems for turning

Applications of PLCs: PLC programming using ladder logic; handshaking and communication between key elements of the cell

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Be able to determine the cost of producing simple components on CNC equipment	1.1 determine the economics of producing a simple component on CNC equipment 1.2 determine the relative merits of manual and CNC machine tools
LO2 Understand the design and construction of CNC machine tools	2.1 assess typical configurations of CNC machine tools and relevant axis conventions 2.2 explain the relationships between the main design features of CNC machine tools 2.3 examine the use of control systems applied to CNC equipment
LO3 Understand the use of tool management in automated environments	3.1 review the requirements of an automated tool management system 3.2 illustrate the uses of adaptive control and sister tooling for tool life management and the use of probing systems for tool setting and tool wear compensation 3.3 analyse the requirements of an automated tool delivery system
LO4 Understand the requirements of a flexible manufacturing cell (FMC) and the uses of programmable logic controllers (PLCs)	4.1 explain the requirements of a flexible manufacturing cell 4.2 discuss the uses of automated material handling systems within the FMC environment 4.3 outline simple programs for applications of PLC cell control.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering –
Issue 3 – November 2017 © Pearson Education Limited 2017

Guidance

Links

This unit may be linked with *Unit 13: Application of Machine Tools* and *Unit 12: Material Handling Systems*.

Essential requirements

Learners will need access to appropriate machine tools and properly trained support staff.

Employer engagement and vocational contexts

Liaison with employers can help provide access to suitable machine tools and equipment. Visits to the learner's workplace or other appropriate industrial facilities, will help foster employer cooperation and help set the focus for the delivery and assessment that have relevance and are of benefit to the whole cohort.

Unit 19: Computer-aided Design and Manufacture

Unit code: M/601/1556

Level: 5

Credit value: 15

Aim

This unit will develop learners' understanding of the practical applications of a Computer-aided Design and Computer-aided Manufacture (CAD/CAM) system.

Unit abstract

Most successful businesses invest substantially in research and development in order to gain competitive advantage. Engineering advances offer sales and marketing teams the ability to sell more products and gain a larger market share. In order to facilitate this, engineers must be able to quickly bring their designs to manufacture to achieve what is known as speed to market. The use of Computer-aided Design (CAD) has allowed engineers to communicate designs quickly. By making use of the geometry and details from CAD models, machines can be quickly and accurately programmed to produce high quality parts. These Computer Numerically Controlled (CNC) machines must receive information in a format that takes account of how part geometry will be achieved by the machining method, for example turning, milling or drilling. Computer-aided Manufacturing (CAM) software is available to accept CAD information. Combined with the knowledge of the engineer in order to sequence the tooling, this enables designs to progress to manufacturing in a relatively short time.

This unit will enable learners to produce component drawings using a CAD system specifically for transfer to a CAM system. They will also develop an understanding of structured data within CAD/CAM systems and the use of data transfer methods. Practical work will include the simulation of cutter paths on a CAM system and the production of a component from a transferred data file.

Learning outcomes

On successful completion of this unit a learner will:

1 Be able to produce a component drawing suitable for transfer onto a CAM system and produce a simple 3D surface

2 Be able to transfer data generated in CAD to a CAM system for subsequent machining

3 Be able to simulate the cutter paths on a CAM system to optimise the machining sequences

4 Understand how to transfer a generated tape file to a CNC machine and produce the component.

Unit content

1 **Be able to produce a component drawing suitable for transfer onto a CAM system and produce a simple 3D surface**

Component drawing: configure the hardware contained within a typical CAD workstation; produce CAD profiles using the more common types of editing facilities; geometry manipulation eg mirror, rotate, copy, array, offset; drawing attributes and structure with specific reference to associated profile data and parts listing

3D surface: use of world axis to produce geometry suitable for transfer to a CAM system; 3D surfaces generated for visualisation and subsequent machining

2 **Be able to transfer data generated in CAD to a CAM system for subsequent machining**

Transfer data: structured CAD data with reference to suitable datum and direction of lines; methods of transfer DYF and IGES; CAD layers used to help tooling sequences with consideration to tool changes

3 **Be able to simulate the cutter paths on a CAM system to optimise the machining sequences**

Cutting and tooling: tooling sequences optimised by using simulated cutting times generated within the CAM system; tooling data files containing calculated speeds and feeds to suit component material; cutting directions and offsets determined with due consideration for component accuracy and finish; clamping and general work holding safety considered with reference to clamping methods including program controlled clamping

CAM software: simulation of a range of cutter paths; component profiles; generation of cutter paths

4 **Understand how to transfer a generated tape file to a CNC machine and produce the component**

Generated tape file: offsets checked and setting values determined using MDI (manual data input) facilities to modify program where required; using buffer stores when applied to large amounts of program data; canned and repetitive cycles analysed and incorporated into the program when appropriate; sub-routines used for pockets, profiles and managed by the main program

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Be able to produce a component drawing suitable for transfer onto a CAM system and produce a simple 3D surface	1.1 produce a working drawing for subsequent manufacture 1.2 demonstrate the significance of drawing attributes for CAD/CAM with specific reference to profile data and parts listing 1.3 produce a variety of geometrical shapes from datum in 3 dimensional space
LO2 Be able to transfer data generated in CAD to a CAM system for subsequent machining	2.1 demonstrate the significance of structured data within a CAD/CAM system 2.2 create a DXF (data exchange file) from a standard drawing file 2.3 produce geometry within a CAM system through the use of a DXF file
LO3 Be able to simulate the cutter paths on a CAM system to optimise the machining sequences	3.1 generate cutter paths on a component profile through the use of suitable CAM software 3.2 demonstrate how to obtain optimum cutting performances by modifying generated cutter paths
LO4 Understand how to transfer a generated tape file to a CNC machine and produce the component	4.1 evaluate common methods of data transfer 4.2 explain the process for inputting a program processed from CAM software to a CNC machine 4.3 justify the method used for producing a component on a suitable CNC machine.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017 © Pearson Education Limited 2017

Guidance

Links

This unit is designed to stand-alone, but can be linked to *Unit 8: Engineering Design*, *Unit 14: Computer-aided Machining*, *Unit 15: Design for Manufacture*, *Unit 31: Value Management* and *Unit 69: Advanced Computer-aided Design Techniques*.

Essential requirements

Centres delivering this unit must be equipped with industrial standard CAD/CAM software and hardware. The CAM software will be equivalent to SMARTCAM, MASTERCAM, ALPHACAM or APS. CAD software similar to ACAD, Release 13 and above would be considered adequate. Suitable machining centres with FANUC or HEIDENHAIN controllers or equivalent would be required also.

Employer engagement and vocational contexts

Centres should try to work closely with industrial organisations in order to bring realism and relevance to the unit. Visits to one or two relevant industrial or commercial organisations which use CAD/CAM techniques will be of value to enhance and support learning.

Unit 20: Quality and Business Improvement

Unit code: A/601/1558

Level: 5

Credit value: 15

Aim

This unit will develop learners' understanding of the principles and applications of quality and business improvement.

Unit abstract

This unit will examine the principles of continuous improvement and will develop an understanding of the key factors that underpin the application of six-sigma methodology. It also aims to introduce the application of failure modes and effect analysis techniques, measurement systems analysis and give opportunities of practical experience to support a basic understanding in mistake/error proofing.

This unit consists of four learning outcomes. The first considers continuous improvement techniques such as quality circles, Kaizen and key performance indicators. The second examines the six-sigma methodology in detail. In the third learning outcome, potential failure modes are examined including an examination of areas of analysis. Finally, worksheets for mistake/error proofing activities are considered.

Learning outcomes

On successful completion of this unit a learner will:

1 Be able to apply continuous improvement principles and techniques

2 Understand the key factors of six-sigma methodology

3 Be able to carry out potential failure modes and effects analysis (FMEA)

4 Be able to create a worksheet of a mistake/error proofing activity and identify suitable solutions.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017 © Pearson Education Limited 2017

Unit content

1 **Be able to apply continuous improvement principles and techniques**

Principles: identification of continuous improvement within a working area or activity eg total company commitment; quality strategy; standard operating procedures; organisational policy and procedures

Techniques: quality improvement terms; quality circles; Kaizen; calculation of key performance indicators

2 **Understand the key factors of six-sigma methodology**

Key factors: procedures – five phases of six-sigma; metric charts; critical to control characteristics

3 **Be able to carry out potential failure modes and effects analysis (FMEA)**

Analysis: areas for analysis eg concept, product, design, process, system, machine

Activities to be analysed: failure modes; effects from failure modes; causes of failure modes

4 **Be able to create a worksheet of a mistake/error proofing activity and identify suitable solutions**

Benefits: improved quality; reduced costs; delivery

Content of worksheet: description of the mistake/error identified; containment action plan; root cause of the mistake/error; corrective action to be taken

Suitable solutions: effectiveness; cost; complexity

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Be able to apply continuous improvement principles and techniques	1.1 identify potential areas for improvements within a working area or activity 1.2 produce standard operating procedures for a working area or activity 1.3 identify and calculate key performance indicators
LO2 Understand the key factors of six-sigma methodology	2.1 explain the key factors of six sigma methodology 2.2 produce a metric chart for a six sigma project 2.3 identify the critical to quality characteristic of a six sigma project
LO3 Be able to carry out potential failure modes and effects analysis (FMEA)	3.1 carry out a potential failure modes and effects analysis 3.2 describe the activities to be analysed
LO4 Be able to create a worksheet of a mistake/error proofing activity and identify suitable solutions	4.1 create a worksheet of a mistake/error proofing activity 4.2 identify suitable solutions.

Guidance

Links

This unit has links with *Unit 17: Business Improvement Technique*s and *Unit 30: Quality Assurance and Management*.

This unit can be linked with the SEMTA Level 4 National Occupational Standards in Business Improvement Techniques, particularly:

- Unit 5: Applying Continuous Improvement Techniques (Kaizen)
- Unit 21: Carrying Out Potential Failure Modes and Effects Analysis (FMEA).

Essential requirements

Centres will need to provide simulated or actual examples for the application of methods used to install, monitor and improve the quality of both products and their associated processes.

Employer engagement and vocational contexts

Liaison with industry should be encouraged in order to develop a valuable, relevant and alternative resource facility.

Unit 21: Materials Engineering

Unit code: F/601/1626

Level: 4

Credit value: 15

Aim

This unit will provide learners with the necessary background knowledge and understanding of the properties, selection, processing and failure of engineering materials.

Unit abstract

The selection of the most appropriate materials for an engineered product and their processing is of prime importance if the product is to be fit for purpose. Engineers must thus be aware of the range of materials at their disposal. Knowledge of the structure of materials and the way in which this affects their properties is also desirable. Material properties may be determined or verified by testing and engineers should be aware of the range of standard tests and test equipment that is used and be able to interpret the test data. Materials generally need to be formed to shape, fabricated or processed in some other way, to make engineering components. The properties of the raw material can affect the choice of process and in some cases the choice of process can affect the final properties of a component. Materials also, for a variety of reasons, sometimes fail in service and engineers need to be aware of the modes and causes of such failure, as well as the preventative methods that may be used, to prolong their service life.

This unit will thus provide learners with the necessary background knowledge and understanding of the properties, testing, treatments, processing, selection, failure modes and prevention of a variety of engineering materials. In addition, this unit offers learners the opportunity to consider environmental issues related to increased productivity and sustainability that lead to less waste and to the more efficient use of energy and resources when selecting materials for particular applications.

Learning outcomes

On successful completion of this unit a learner will:

1 Be able to determine the properties and selection criteria of materials from tests and data sources

2 Understand the relationships between manufacturing processes and material behaviour

3 Be able to select suitable materials and processing methods for a specific product

4 Understand the in-service causes of failure of engineering materials.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017

Unit content

1 **Be able to determine the properties and selection criteria of materials from tests and data sources**

Criteria for material selection: definitions of material properties and characteristics appropriate to the learner's programme of study eg mechanical, physical, chemical, process characteristics and costs for range of materials (metals, ceramics, polymers, and composites)

Categorise materials: an appreciation of the properties of metals, ceramics, polymers and composites; recognition of micro structural characteristics of the more commonly used engineering materials

Materials testing: tests to determine the properties of commonly used engineering materials eg metals, ceramics, polymers and composites (such as electrical conductivity/resistivity, magnetic susceptibility, mechanical strength, hardness, toughness, fatigue and creep resistance, corrosion and reactivity, wear resistance, optical and thermal properties, formability); appropriate statistical methods and the processing of test data

Data sources: published data eg British Standards, ISO, product data sheets, IT sources, standard published data sources, manufacturers' literature, job-specific information such as specifications, test data and engineering drawings; assessment of data reliability

2 **Understand the relationships between manufacturing processes and material behaviour**

Treatment processes: heat treatments eg quench and precipitation hardening processes, complex heat treatments (such as conjoint mechanical/thermal treatments), glass transitions; other treatment processes eg coated materials (such as CVD/vacuum coating processes), chip technology; surface treatments/surface engineering, polymer treatments, composites/powder produced materials, matrix/reinforcement relationships, dispersion strengthening

Liquid processing: metal casting and injection moulding/extrusion of polymers; effect of processing on structure and properties eg grain structure, porosity

Mechanical processing: effect on structure and properties illustrated by a range of processes eg mechanical working of metals, powder processing of metals and ceramics, extrusion and forming of polymer sheet, welding, use of adhesives; effect of processing on structure and properties eg residual stresses, work hardening

Composition and structure: eg alloying, co-polymerisation; additives, cross-linking, crystallinity, lattice structure, slip planes and their effect on properties of parent material

3 **Be able to select suitable materials and processing methods for a specific product**

Design constraints: eg working conditions such as applied forces, environment, electrical/magnetic requirements, shape, form and function of the product

Materials, properties and processing: inter-relationship between product design, material selection and processing methods; merit index/index of suitability; ability to be re-used

Processing limitations: effects of the manufacturing processing capabilities on the structure of materials and preventing or facilitating product design, effect on environment (such as sustainability, emissions, energy conservation)

4 **Understand the in-service causes of failure of engineering materials**

Causes of failure: failure of material categories (metals, ceramics, polymers and composites) eg creep, fatigue, impact, overstressing, corrosion, temperature, thermal cycling, residual stresses, stress relaxation, degradation (composition change), radiation, electrical breakdown, or combinations of these

Service life: contributory effects of service conditions to failure eg inappropriate maintenance, inappropriate use, faults in manufacture, material selection and design faults, changes in service conditions such as environment, loading and temperature

Estimation: methods of investigating failure and the preparation of estimates of product service life that require the use of calculations eg creep or fatigue failure

Improving service life: recommending remedial and/or preventative measures eg changes to material, product design, protective systems for corrosion and degradation, adjustment loading and working temperature

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Be able to determine the properties and selection criteria of materials from tests and data sources	1.1 detail the appropriate properties and criteria for the selection of a metallic, ceramic, polymer and composite material 1.2 explain the particular characteristics related to the microstructure and macroscopic behaviour of the four categories of engineering materials 1.3 generate and process test data to assess material properties for two categories of material 1.4 investigate and assess the quality of suitable data from three different sources
LO2 Understand the relationships between manufacturing processes and material behaviour	2.1 explain how one heat treatment process and two other treatment processes affect the structure, properties and behaviour of the parent material 2.2 explain how one liquid processing method and two mechanical processing methods affect the structure, properties and behaviour of the parent material 2.3 investigate how the composition and structure of metal alloys, polymers and polymer matrix composites influence the properties of the parent material
LO3 Be able to select suitable materials and processing methods for a specific product	3.1 analyse the function/s of a product in terms of the materials' constraints on its design 3.2 identify the required properties for the product and select the most appropriate materials and processing methods 3.3 identify and explain the possible limitations on the product imposed by the processing and by the need to safeguard the environment and minimise costs

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO4 Understand the in-service causes of failure of engineering materials	4.1 explain the common causes of in-service failure for products or structures produced from each or a combination of the four categories of engineering materials 4.2 for one product or material structure, identify and explain the in-service conditions that may contribute to early failure 4.3 explain the methods for investigating materials failure and for estimating product service life, when a product is subject to creep and fatigue loading 4.4 determine and make recommendations for remedial/preventive measures for a given product or materials structure, that will help improve its service life.

Guidance

Links

Successful completion of *Unit 8: Engineering Design* and this unit would enable learners to meet, in part, the Engineering Technician (Eng Tech) and Incorporated Engineer (IEng) requirements laid down in the UK Engineering Council Standard for Professional Engineering Competence (UK-SPEC) Competence B2, 'Identify, organise and use resources effectively to complete tasks, with consideration for cost, quality, safety and environmental impact'.

Essential requirements

Learner access to suitable materials testing equipment, specimens and test instrumentation is required. The range of tests chosen will depend on the learner's working environment and particular needs but will need to include, as a minimum, tests that involve metals and polymers. Sample materials from each of the four categories for inspection, as well as products/structures produced from these categories of material, are also required.

Employer engagement and vocational contexts

Liaison with employers would prove of benefit to centres, especially if they are able to offer help with the provision of a suitable materials testing and/or processing/fabrication environment.

Unit 22: Programmable Logic Controllers

Unit code: A/601/1625

Level: 4

Credit value: 15

Aim

The aim of this unit is to investigate programmable logic controller (PLC) concepts and their applications in engineering.

Unit abstract

The unit focuses on the design and operational characteristics and internal architecture of programmable logic control systems. It examines the signals used and the programming techniques that can be applied. The unit also provides learners with the opportunity to produce and demonstrate a program for a programmable logic controller device (for example produce a programme for an engineering application, store, evaluate and justify approaches taken).

Learning outcomes

On successful completion of this unit a learner will:

1 Understand the design and operational characteristics of a PLC system

2 Understand PLC information and communication techniques

3 Be able to apply programmable logic programming techniques

4 Understand alternative implementations of programmable control.

Unit content

1 **Understand the design and operational characteristics of a PLC system**

Design characteristics: unitary; modular; rack-mounted

Input and output devices: mechanical switches; non-mechanical digital sources; transducers; relays

Communication links: twisted pair; coaxial; fibre-optic; networks

Internal architecture: central processor unit (CPU); arithmetic logic unit (ALU); storage devices; memory; opto-isolators; input and output units; flags; shift; registers

Operational characteristics: scanning; performing logic operations; continuous updating; mass input/output (I/O) copying

2 **Understand PLC information and communication techniques**

Forms of signal: analogue (0-10 v dc, 4-20mA); digital

Digital resolution and relationships: 9-bit; 10-bit; 12-bit

Number systems: decimal; binary; octal; hexadecimal; Binary-Coded Decimal (BCD)

Evaluate communication standards: comparison of typical protocols used in signal communication

Evaluate networking methods and standards: master to slave; peer to peer; ISO; IEE; MAP

Logic functions: writing programmes using logic functions based on relay ladder logic (AND; OR; EXCLUSIVE OR; NAND; NOR)

3 **Be able to apply programmable logic programming techniques**

Write programs: use of ladder and logic diagrams; statement lists; Boolean algebra; function diagrams; graphical programming languages; production of a PLC

Advanced functions: less than; greater than; binary to BCD conversion; proportional feedback control

Producing and storing text: contact labels; rung labels; programming lists; cross-referencing

Test and debug programs: forcing inputs, forcing outputs; changing data; comparing files (tapes, EPROM, disc); displayed error analysis

Associated elements: contacts; coils; timers; counters; override facilities; flip-flops; shift registers; sequencers

4 **Understand alternative implementations of programmable control**

PICs and other programmable devices: specification and use of PICs and other programmable devices; embedded controllers

PLC simulators: compare operation and functionality; advantages and limitations

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Understand the design and operational characteristics of a PLC system	1.1 evaluate the design characteristics of typical programmable logic devices 1.2 describe different types of input and output device 1.3 evaluate the different types of communication link used in programmable logic control systems 1.4 describe the internal architecture and operational characteristics of the CPU of a typical programmable logic device
LO2 Understand PLC information and communication techniques	2.1 evaluate the different forms of signal used in programmable logic control 2.2 describe the resolution and relationship between analogue inputs and outputs and word length 2.3 express numbers using different number systems 2.4 describe typical protocols used in signal communication and evaluate networking methods and networking standards
LO3 Be able to apply programmable logic programming techniques	3.1 identify elements associated with the preparation of a programmable logic controller program 3.2 write programs using logic functions based on relay ladder logic 3.3 evaluate the range and type of advanced functions of programmable logic controllers 3.4 use and justify methods of testing and debugging hardware and software
LO4 Understand alternative implementations of programmable control	4.1 evaluate PICs and other programmable devices as programmable devices and embedded controllers 4.2 compare the operation, functionality, advantages and limitations of PLC simulators.

Guidance

Links

This unit may be linked to *Unit 46: Plant and Process Control*, *Unit 49: Computer Control of Plant*, *Unit 58: Microprocessor Systems* and *Unit 71: Combinational and Sequential Logic*.

Essential requirements

Centres delivering this unit must be equipped with, or have access to, industrial-standard programmable logic control units and development software.

Employer engagement and vocational contexts

Visits to industrial PLC installations will be of value to supplement the learning activities.

Unit 23: Engineering Procurement

Unit code:	F/601/1500
Level:	4
Credit value:	15

Aim

This unit examines procurement or purchasing strategies and their importance in engineering management. The unit shows how procurement contributes to profit and how it helps to maintain a competitive edge.

Unit abstract

Procurement involves the input of goods and services and the interface between the supplier and the client. Large companies organise themselves with a purchasing or materials department to carry out the procurement function. Since the cost of manufacture is mostly made up of material spend as opposed to labour or overhead, companies need to focus on the amount spent on materials. This in turn puts an onus on engineers to design products, organise manufacturing processes and layout a factory with the use of materials in mind. For example, engineers ought to design products with standard sized components to take advantage of lower costs. In fact, many companies deploy engineers into their purchasing departments in order to capitalise on opportunities for cost savings. This unit gives learners an understanding of procurement strategies and their importance in engineering management. The unit also shows how procurement contributes to profit and how it helps to maintain a competitive edge.

The unit starts with an introduction and development of the principles and applications of resource (materials and equipment) management in an engineering operation. It then takes the learner into the strategies for procurement such as systems, roles, risks and managing procurement. Learners then consider the procurement issues of contract, sourcing and evaluation of communications, finance and delivery.

Learning outcomes

On successful completion of this unit a learner will:

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

2 Understand how the procurement strategy contributes to the achievement of an engineering operation's objectives

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

4 Understand procurement pricing and management strategies within an engineering organisation

5 Be able to review and evaluate procurement strategies within an engineering organisation.

Unit content

1 **Understand the principles of resource management and its application to an engineering operation**

Methods: selection; acquisition; maintenance; replacement criteria

Principles: procurement strategy; specification; supplier identification; selection criteria; working with specialist suppliers; stock control

2 **Understand how the procurement strategy contributes to the achievement of an engineering operation's objectives**

Systems and processes: standard specification; tendering; estimating/quoting; methods of procurement eg centralised, contract, lease, Pareto analysis, 'just in time' (JIT); equipment; materials; services; terms and conditions

Procurement officer role: assessing operational needs; selecting suppliers; quality and quantity control; timing; company policies; budgetary restrictions eg discounts, receipt and control of purchases, wastage factors

Risks: financial; physical; task duplication; direct and indirect costs; effect on the internal and external customer eg quality issues, legal implications; effect on process and outcome activities of organisations

Managing procurement: profit opportunities; direct and indirect cost saving opportunities; minimising risk; maximising profit; approved supplier lists; evaluating the 'best deal'; performance indicators and benchmarking

3 **Understand the importance of the procurement contract and its application to engineering operations**

Contract: definition; different forms; parties; essentials for a valid contract; rules of offer and acceptance; terms eg express/implied, conditions/warranties; vitiating factors eg misrepresentation, fundamental mistake, breaches, fraud

Sourcing issues: method of supply eg buying products/services, tendering, sub-contracting/outsourcing; value for money; hygiene factors; range; choice; service guarantee; legal and contractual compliance; trace origin data; yield; methods of payment; credit and price; negotiating skills

Evaluation: communication; finance; delivery; compliance with specified requirements; packaging; industrial relations; attitude to customers; sample testing and defect elimination

4 **Understand procurement pricing and management strategies within an engineering organisation**

Pricing management: techniques; negotiating price reductions; controlling or resisting price increases; quantity discounts; prompt payment discounts

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

5 **Be able to review and evaluate procurement strategies within an engineering organisation**

Review: standard specifications; terms and conditions; monitoring; redeveloping strategy; contemporary developments; comparing and contrasting purchasing options

Evaluate: cost models eg return on investment (ROI), productivity gain, human resource benefits

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Understand the principles of resource management and its application to an engineering operation	1.1 assess the methods available for managing materials 1.2 explain the principles involved when procuring equipment and the ongoing requirements over the life of that equipment
LO2 Understand how the procurement strategy contributes to the achievement of an engineering operation's objectives	2.1 recommend procurement systems and processes with related performance indicators and benchmarking for an engineering operation 2.2 analyse the risks involved in a procurement strategy 2.3 examine the role of the procurement officer within an engineering operation
LO3 Understand the importance of the procurement contract and its application to engineering operations	3.1 explain the importance of a procurement contract 3.2 evaluate the sourcing issues for a procurement situation using a range of suppliers 3.3 review the management techniques used to appraise and evaluate the suppliers of an engineering management operation
LO4 Understand procurement pricing and management strategies within an engineering organisation	4.1 explain the management strategies that can be used to maximise the purchasing power of the procurement officer 4.2 compare pricing management techniques used in an engineering procurement situation
LO5 Be able to review and evaluate procurement strategies within an engineering organisation	5.1 plan a review and evaluation to measure the success of a company's procurement strategy 5.2 conduct a review and evaluation for a procurement scenario in an engineering operation.

Guidance

Links

This unit can be linked to *Unit 7: Business Management Techniques* and *Unit 11: Supply Chain Management*.

This unit can be linked to the SEMTA Level 4 National Occupational Standards in Engineering Management, particularly Unit 4.17: Obtain Resources for the Implementation of Engineering Activities.

Essential requirements

There are no essential requirements for this unit.

Employer engagement and vocational contexts

Centres should try to work closely with industrial organisations to bring realism and relevance to the unit.

Access to procurement sections of local organisations, if possible, provides a useful information source. Part-time learners working in procurement can be used as a resource by sharing their experiences of different company approaches to procurement.

Unit 24: Applications of Pneumatics and Hydraulics

Unit code: J/601/1496

Level: 4

Credit value: 15

Aim

This unit aims to extend learners' understanding of pneumatic and hydraulic fluid power systems and their modern industrial applications and enable them to design fluid power circuits.

Unit abstract

Pneumatics and hydraulic systems involve the transmission of force and motion through a fluid. With pneumatic systems, the fluid is very often compressed air, although inert gases are also used in some applications. With hydraulic systems, the fluid is generally specially formulated oil, but water might also be used in some applications.

Pneumatic and hydraulic systems are to be found in transport, manufacturing, mechanical handling and process control. They each have their advantages and disadvantages. Gases have a low density and are compressible whilst liquids have a much higher density and are almost incompressible. As a result, hydraulic systems generally operate at higher pressures and can deliver very large positive forces such as those required in hydraulic presses, lifts and earth moving equipment. Pneumatic systems have a softer action and are not able to deliver such large forces. Compressed air is however readily available as a service in many industrial installations. It can be supplied over relatively long distances and is widely used in actuation and control systems and in robots.

This unit aims to extend the learner's knowledge and understanding of fluid power systems in modern industry. Learners will study pneumatic and hydraulic circuit symbols and diagrams and consider circuit designs. They will also examine the characteristics and selection of components and equipment and evaluate relevant industrial applications of pneumatics and hydraulics.

Learning outcomes

On successful completion of this unit a learner will:

1 Be able to read and interpret pneumatic and hydraulic fluid power diagrams

2 Understand the construction, function and operation of pneumatic and hydraulic components, equipment and plant

3 Be able to design pneumatic and hydraulic circuits

4 Be able to evaluate and justify industrial applications of pneumatics and hydraulics.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017

Unit content

1 **Be able to read and interpret pneumatic and hydraulic fluid power diagrams**

Pneumatic and hydraulic symbols: read and interpret eg energy conversion, valve, energy transmission, control and miscellaneous symbols; use of appropriate British and International Standards eg BS 2917, ISO 1219-2 (2009), ISO 9461 (Hydraulics), CETOP, RP68P, ISO 5599 (Pneumatics)

Fluid power diagrams: read and interpret system-layout and circuit diagrams eg use of ISO 1219-2 Part 2, component lists, component data sheets, displacement-step diagrams, operating instructions, installation and maintenance manuals; applications eg logic, memory and multi-actuator sequential circuit operation, cascading techniques, linear and rotary actuation circuits

2 **Understand the construction, function and operation of pneumatic and hydraulic components, equipment and plant**

Pneumatic equipment: types, construction, function and operation eg air compressors, coolers, dryers, receivers, distribution equipment, fluid plumbing and fittings, drain traps, FRL air service units, valves, actuators, seals

Hydraulic equipment: types, construction, function and operation eg fluids, pumps, motors, actuators, reservoirs, accumulators, fluid plumbing and fittings, valves, filters, seals, gauges

Performance characteristics: air compressors eg volumetric efficiency, compression ratio, isothermal efficiency; hydraulic pumps eg operating efficiency, losses, flow rate, operating pressure, shaft speed, torque and power

3 **Be able to design pneumatic and hydraulic circuits**

Pneumatic circuits: eg directional control, piloted control, reciprocating control, logic, memory, multi-actuator circuits with sequential operation, cascading techniques, stepper circuits, pulsed signals, latching circuits, direction and speed control of rotary actuators and air motors

Hydraulic circuits: eg sequential operation of multi-actuator circuits, regenerative circuits, counterbalance circuits, 'meter-in' and 'meter-out' circuits, bleed-off circuits, direction and speed control of hydraulic motors

Electro-pneumatic and electro-hydraulic circuits: use of electronic logic devices and systems and their interface with fluid power circuits; solenoid valve arrangements

Emergency 'fail safe' circuits: use of emergency stop circuits to give predictable 'parking' positions for linear actuators, emergency stopping circuits for rotary actuators and motors, thermal and pressure relief circuits, 'fail safe' circuit arrangements

4 **Be able to evaluate and justify industrial applications of pneumatics and hydraulics**

Industrial applications: measurements of process and/or machine parameters in selected applications eg manufacturing, processing, transportation, utilities, operation of plant, machinery, equipment, controlling processes and plant

Technical requirements: design and selection of equipment, materials and components; installation; test and commissioning procedures

Commercial aspects: eg capital costs, running costs, maintenance, flexibility of proposed system, future expansion and/or changes to installation

Health and safety: requirements of safety legislation and relevant regulations eg Health and Safety at Work Act 1974, Pressure Systems and Transportable Gas Containers Regulations 1989, Pressure System Safety Regulations 2000, SI 2000 No 128

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Be able to read and interpret pneumatic and hydraulic fluid power diagrams	1.1 recognise and describe given fluid power symbols that conform to the latest ISO 1219 standards or their national/international equivalent 1.2 from a given system diagram, read, interpret and explain the operation of either a pneumatic or hydraulic multi-actuator sequential system that uses a minimum of four actuators 1.3 produce a suitable circuit design drawing for either a pneumatic or hydraulic reversible rotary actuation system that includes speed control in both directions
LO2 Understand the construction, function and operation of pneumatic and hydraulic components, equipment and plant	2.1 identify the features, describe the function and explain the operation of given items of pneumatic and hydraulic equipment 2.2 analyse, compare and contrast the performance characteristics for two given items of pneumatic and two given items of hydraulic equipment
LO3 Be able to design pneumatic and hydraulic circuits	3.1 design and produce a circuit design diagram for either a pneumatic or hydraulic multi-actuator sequential operation circuit, that includes emergency stop functions 3.2 design and produce a circuit design diagram for either a pneumatic or hydraulic rotary actuation system that includes speed control in both directions 3.3 design and produce a circuit design diagram for either an electro-pneumatic or electro-hydraulic system arrangement 3.4 design and produce a circuit design for either a pneumatic or hydraulic 'fail-safe' circuit application
LO4 Be able to evaluate and justify industrial applications of pneumatics and hydraulics	4.1 evaluate and justify the use of either pneumatic or hydraulic fluid power technology for a given industrial application 4.2 evaluate and discuss the technical requirements and commercial considerations for the given industrial application 4.3 identify and discuss the appropriate health and safety requirements for the design, installation, maintenance and use of the given industrial application.

Guidance

Links

This unit has links with *Unit 22: Programmable Logic Controllers* and *Unit 41: Fluid Mechanics*.

Essential requirements

Centres must be equipped with, or have access to, industrial standard pneumatic and hydraulic equipment and test assemblies/facilities. In addition, relevant British and International Standards and British Fluid Power Association publications need to be available.

Employer engagement and vocational contexts

Liaison with employers would prove of benefit to centres, especially if they are able to offer help with the provision of suitable industrial hydraulic and/or pneumatic equipment and test facilities.

Unit 25: Engine and Vehicle Design and Performance

Unit code: A/601/1494

Level: 5

Credit value: 15

Aim

This unit will develop learners' knowledge of engine and vehicle design and will enable them to evaluate engine and vehicle performance.

Unit abstract

This unit will examine the aspects of design that relate to the function of engines, with a particular emphasis on performance. Learners will examine vehicle design for light and heavy vehicles with a view to understanding performance curves and other data used to evaluate vehicle performance. Learners will also appreciate possible future developments in vehicle engineering and in particular the use of new technologies, materials and design method.

Learners are introduced to engine design features, operating parameters and the likely effects when these are varied or altered. They then investigate engine performance and will analyse the data obtained from engine trials. Learners are introduced to the design features of light and heavy vehicles with particular emphasis on aerodynamics and transmission systems. They will then evaluate vehicle performance under different operating conditions and interpret vehicle performance curves.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand engine design features

2 Be able to evaluate engine performance

3 Understand vehicle design features

4 Be able to evaluate vehicle performance.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017

Unit content

1 **Understand engine design features**

Engine design features: eg cylinder bore diameter, stroke length, con-rod to crank ratio, the number and arrangements of cylinders, overall engine dimensions, piston design, compression ratio, combustion chambers, camshaft design, crankshaft design, use of emerging technologies in engine design, new materials, alternate and multi fuel engine design (Electric, Compressed Natural Gas (CNG), Liquid Natural Gas (LNG), gasoline-electrical hybrid)

2 **Be able to evaluate engine performance**

Performance characteristics: torque; power; mechanical efficiency; thermal efficiency; volumetric efficiency; mean effective pressure; specific fuel consumption; emission control assessment

Engine performance mapping: graphical account of the role of map data; mapping procedure; visual interpretation of a fuel map and ignition map; fuel/ignition maps for different engine performance applications eg economy, power and torque

Performance curves: curves eg for spark ignition (SI), combustion ignition (CI) and pressure charged, rotary engines; engine test at various engine speeds; critical evaluation of air/fuel ratio; torque, power; exhaust emissions; fuel consumption; significance of the standards used to measure engine power eg BSAU, DIN, SAE, EEC; application of engine performance curves and design to the selection of appropriate power units for specific tasks

3 **Understand vehicle design features**

Features of vehicle design: light and heavy vehicles; body type; body shapes and design; aerodynamic devices; transmission; 5-speed; 6-speed; range change; splitter; four-wheel drive; multiple axles; chassis; laden weight; unladen weight; power to weight ratio; use and applications of new technologies, materials and design methods

4 **Be able to evaluate vehicle performance**

Performance monitoring: tractive effort; tractive resistance; air; rolling and gradient eg power available, power required

Performance characteristics: performance curves for different vehicles; tractive effort available for different combinations; tractive effort required for types of vehicle eg in laden, unladen conditions; acceleration possible with different combinations of engines; transmissions and vehicles; gradeability; the change in engine speed that results when changing from one gear ratio to another eg various gear ratios and transmission units; the effects of a change in engine speed produced by a gear change on engine torque, power and fuel consumption, the road speed of a vehicle

Vehicle performance curves: for selecting appropriate vehicles from data calculated

Air resistance: air resistance using the formula $R_A = K V^2 A$; air resistance variation with engine speed and its effects on fuel economy; Cd, CdA, typical values for light and heavy vehicles; methods used to reduce air resistance of vehicles

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Understand engine design features	1.1 identify and discuss the engine design features that contribute to the selection of an engine for a given application 1.2 analyse the effects of altering engine design features for a given application
LO2 Be able to evaluate engine performance	2.1 determine the performance characteristics of a given engine 2.2 carry out and record the outcomes of an engine performance mapping procedure 2.3 interpret performance curves and select and justify the use of an appropriate engine for a given application
LO3 Understand vehicle design features	3.1 discuss the features of vehicle design that contribute to the selection of a vehicle for a given application 3.2 analyse the effects of altering the features of vehicle design for a given application
LO4 Be able to evaluate vehicle performance	4.1 explain the terms used in vehicle performance monitoring 4.2 determine the performance characteristics of a given vehicle 4.3 perform calculations to determine vehicle air resistance and explain the effects of air resistance on engine speed and fuel economy 4.4 interpret performance curves and select an appropriate vehicle from given information.

Guidance

Links

This unit has links with *Unit 74: Vehicle Fault Diagnosis*, *Unit 75: Vehicle Systems and Technology* and *Unit 79: Vehicle Electronics*.

Essential requirements

Centres will need to provide access to suitable engine test facilities and manufacturers' manuals and performance data.

Employer engagement and vocational contexts

Delivery would benefit from visits to motor industry test facilities for engines and/or vehicles and the attendance of guest speakers with experience of engine/vehicle design, testing or refurbishment.

Unit 26: Employability Skills

Unit code: A/601/0992

Level: 5

Credit value: 15

Aim

This unit provides learners with the opportunity to acquire honed employability skills required for effective employment.

Unit abstract

All learners at all levels of education and experience require honed employability skills as a prerequisite to entering the job market. This unit gives learners an opportunity to assess and develop an understanding of their own responsibilities and performance in, or when entering, the workplace.

It considers the skills required for general employment, such as interpersonal and transferable skills, and the dynamics of working with others in teams or groups including leadership and communication skills.

It also deals with the everyday working requirement of problem solving which includes the identification or specification of the 'problem', strategies for its solution and then evaluation of the results through reflective practices.

Learning outcomes

On successful completion of this unit a learner will:

1 Be able to determine own responsibilities and performance

2 Be able to develop interpersonal and transferable skills

3 Understand the dynamics of working with others

4 Be able to develop strategies for problem solving.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017 © Pearson Education Limited 2017

Unit content

1 **Be able to determine own responsibilities and performance**

Own responsibilities: personal responsibility; direct and indirect relationships and adaptability, decision-making processes and skills; ability to learn and develop within the work role; employment legislation, ethics, employment rights and responsibilities

Performance objectives: setting and monitoring performance objectives

Individual appraisal systems: uses of performance appraisals eg salary levels and bonus payments, promotion strengths and weaknesses, training needs; communication; appraisal criteria eg production data, personnel data, judgemental data; rating methods eg ranking, paired comparison, checklist, management by objectives

Motivation and performance: application and appraisal of motivational theories and techniques, rewards and incentives, manager's role, self-motivational factors

2 **Be able to develop interpersonal and transferable skills**

Effective communication: verbal and non-verbal – awareness and use of body language, openness and responsiveness, formal and informal feedback to and from colleagues; ICT as an effective communication medium; team meetings

Interpersonal skills: personal effectiveness; working with others; use of initiative; negotiating skills; assertiveness skills; social skills

Time management: prioritising workload; setting work objectives; making and keeping appointments; working steadily rather than erratically; time for learning; reliable estimate of task time

Problem solving: problem analysis; researching changes in the workplace; generating solutions; choosing a solution

3 **Understand the dynamics of working with others**

Working with others: nature and dynamics of team and group work; informal and formal settings, purpose of teams and groups eg long-term corporate objectives/strategy; problem solving and short-term development projects; flexibility/adaptability; team player

Teams and team building: selecting team members eg specialist roles, skill and style/approach mixes; identification of team/work group roles; stages in team development eg team building, identity, loyalty, commitment to shared beliefs, team health evaluation; action planning; monitoring and feedback; coaching skills; ethics; effective leadership skills, eg, setting direction, setting standards, motivating, innovative, responsive, effective communicator, reliability, consistency

4 **Be able to develop strategies for problem solving**

Specification of the problem: definition of the problem; analysis and clarification

Identification of possible outcomes: identification and assessment of various alternative outcomes

Tools and methods: problem-solving methods and tools

Plan and implement: sources of information; solution methodologies; selection and implementation of the best corrective action eg timescale, stages, resources, critical path analysis

Evaluation: evaluation of whether the problem was solved or not; measurement of solution against specification and desired outcomes; sustainability

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Be able to determine own responsibilities and performance	1.1 develop a set of own responsibilities and performance objectives 1.2 evaluate own effectiveness against defined objectives 1.3 make recommendations for improvement 1.4 review how motivational techniques can be used to improve quality of performance
LO2 Be able to develop interpersonal and transferable skills	2.1 develop solutions to work based problems 2.2 communicate in a variety of styles and appropriate manner at various levels 2.3 identify effective time management strategies
LO3 Understand the dynamics of working with others	3.1 explain the roles people play in a team and how they can work together to achieve shared goals 3.2 analyse team dynamics 3.3 suggest alternative ways to complete tasks and achieve team goals
LO4 Be able to develop strategies for problem solving	4.1 evaluate tools and methods for developing solutions to problems 4.2 develop an appropriate strategy for resolving a particular problem 4.3 evaluate the potential impact on the business of implementing the strategy.

Guidance

Links

This unit links with the *Personal and Professional Development*, the W*ork-Based Experience* and *Research Project* units. It also links with the following Asset Skills cross-sectoral Employability Matrix:

- B2.4: Plan and manage time, money and other resources to achieve goals
- B3.3: Find and suggest new ways to achieve goals and get the job done and achieve goals
- B4.5: Plan for and achieve your learning goals
- C1.1: Understand the roles people play in a group and how you can best work with them
- C1.7: Lead or support and motivate a team to achieve high standards
- C2.6: Find new and creative ways to solve a problem.

Essential requirements

Learners will need access to a range of work-related exemplars (for example, appraisal and development systems, team health checks, job descriptions, action plans, communication strategies).

Employer engagement and vocational contexts

Delivery of this unit will benefit from centres establishing strong links with employers willing to contribute to the delivery of teaching, work-based placements and/or detailed case study materials.

Unit 27: Personal and Professional Development

Unit code: T/601/0943

Level: 5

Credit value: 15

Aim

This unit aims to help the learner become an effective and confident self-directed employee. This helps the learner become confident in managing own personal and professional skills to achieve personal and career goals.

Unit abstract

This unit is designed to enable learners to assess and develop a range of professional and personal skills in order to promote future personal and career development. It also aims to develop learners' ability to organise, manage and practise a range of approaches to improve their performance as self-directed learners in preparation for work or further career development.

The unit emphasises the needs of the individual but within the context of how the development of self-management corresponds with effective team management in meeting objectives.

Learners will be able to improve their own learning, be involved in teamwork and be more capable of problem solving through the use of case studies, role play and real-life activities.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand how self-managed learning can enhance lifelong development

2 Be able to take responsibility for own personal and professional development

3 Be able to implement and continually review own personal and professional development plan

4 Be able to demonstrate acquired interpersonal and transferable skills.

Unit content

1 **Understand how self-managed learning can enhance lifelong development**

Self-managed learning: self-initiation of learning processes; clear goal setting, eg aims and requirements, personal orientation achievement goals, dates for achievement, self-reflection

Learning styles: personal preferences; activist; pragmatist; theorist; reflector, eg reflexive modernisation theory; Kolb's learning cycle

Approaches: learning through research; learning from others, eg mentoring/coaching, seminars, conferences, secondments, interviews, use of the internet, social networks, use of bulletin boards, news groups

Effective learning: skills of personal assessment; planning, organisation and evaluation

Lifelong learning: self-directed learning; continuing professional development; linking higher education with industry, further education, Recognition of Prior Learning, Apprenticeships, Credit Accumulation and Transfer Schemes

Assessment of learning: improved ability range with personal learning; evidence of improved levels of skill; feedback from others; learning achievements and disappointments

2 **Be able to take responsibility for own personal and professional development**

Self appraisal: skills audit (personal profile using appropriate self-assessment tools); evaluating self-management; personal and interpersonal skills; leadership skills

Development plan: current performance; future needs; opportunities and threats to career progression; aims and objectives; achievement dates; review dates; learning programme/activities; action plans; personal development plan

Portfolio building: developing and maintaining a personal portfolio

Transcripts: maintaining and presenting transcripts including curriculum vitae

3 **Be able to implement and continually review own personal and professional development plan**

Learning styles and strategies: types of styles; awareness of own personal style; impact of personal style and interactions with others

Learning from others: formal learning and training; observation; mentoring; supervision; tutorials; informal networks; team members; line managers; other professionals

Evaluation of progress: setting and recording of aims and objectives; setting targets; responding to feedback; re-setting aims and targets; establishing and recognising strengths and weaknesses; directions for change; cycles of activity (monitoring, reflecting and planning)

4 **Be able to demonstrate acquired interpersonal and transferable skills**

Transferable skills: personal effectiveness (ability to communicate effectively at all levels, initiative, self-discipline, reliability, creativity, problem solving)

Verbal and non-verbal communication: effective listening, respect for others' opinions; negotiation; persuasion; presentation skills; assertiveness; use of ICT

Delivery formats: ability to deliver transferable skills using a variety of formats

Working with others: team player; flexibility/adaptability; social skills

Time management: prioritising workloads; setting work objectives; using time effectively; making and keeping appointments; reliable estimates of task time

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Understand how self-managed learning can enhance lifelong development	1.1 evaluate approaches to self managed learning 1.2 propose ways in which lifelong learning in personal and professional contexts could be encouraged 1.3 evaluate the benefits of self-managed learning to the individual and organisation
LO2 Be able to take responsibility for own personal and professional development	2.1 evaluate own current skills and competencies against professional standards and organisational objectives 2.2 identify own development needs and the activities required to meet them 2.3 identify development opportunities to meet current and future defined needs 2.4 devise a personal and professional development plan based on identified needs
LO3 Be able to implement and continually review own personal and professional development plan	3.1 discuss the processes and activities required to implement the development plan 3.2 undertake and document development activities as planned 3.3 reflect critically on own learning against original aims and objectives set in the development plan 3.4 update the development plan based on feedback and evaluation
LO4 Be able to demonstrate acquired interpersonal and transferable skills	4.1 select solutions to work-based problems 4.2 communicate in a variety of styles and appropriate manner at various levels 4.3 evaluate and use effective time management strategies.

Guidance

Links

The unit links with U*nit 26: Employability Skills*.

Essential requirements

There are no essential requirements for this unit.

Employer engagement and vocational contexts

Delivery of this unit will benefit from centres establishing strong links with employers willing to contribute to the delivery of teaching, work-based placements and/or detailed case study materials.

Unit 28: Research Project

Unit code: K/601/0941

Level: 5

Credit value: 20

Aim

To develop learners' skills of independent enquiry and critical analysis by undertaking a sustained research investigation of direct relevance to their Higher Education programme and professional development.

Unit abstract

This unit is designed to enable learners to become confident using research techniques and methods. It addresses the elements that make up formal research including the proposal, a variety of research methodologies, action planning, carrying out the research itself and presenting the findings. To complete the unit satisfactorily, learners must also understand the theory that underpins formal research.

The actual research depends on the learner, the context of their area of learning, their focus of interest and the anticipated outcomes. The unit draws together a range of other areas from within the programme to form a holistic piece of work that will makes a positive contribution to the learner's area of interest. Learners should seek approval from their tutors before starting their research project

Learning outcomes

On successful completion of this unit a learner will:

1 Understand how to formulate a research specification

2 Be able to implement the research project within agreed procedures and to specification

3 Be able to evaluate the research outcomes

4 Be able to present the research outcomes.

Unit content

1 **Understand how to formulate a research specification**

Research formulation: aims and objectives; rationale for selection; methodology for data collection and analysis; literature review; critique of references from primary sources, eg questionnaires, interviews; secondary sources, eg books, journals, internet; scope and limitations; implications, eg resources

Hypothesis: definition; suitability; skills and knowledge to be gained; aims and objectives; terms of reference; duration; ethical issues

Action plan: rationale for research question or hypothesis; milestones; task dates; review dates; monitoring/reviewing process; strategy

Research design: type of research, eg qualitative, quantitative, systematic, original; methodology; resources; statistical analyses; validity; reliability; control of variables

2 **Be able to implement the research project within agreed procedures and to specification**

Implement: according to research design and method; test research hypotheses; considering test validity; reliability

Data collection: selection of appropriate tools for data collection; types, eg qualitative, quantitative; systematic recording; methodological problems, eg bias, variables and control of variables, validity and reliability

Data analysis and interpretation: qualitative and quantitative data analysis – interpreting transcripts; coding techniques; specialist software; statistical tables; comparison of variable; trends; forecasting

3 **Be able to evaluate the research outcomes**

Evaluation of outcomes: an overview of the success or failure of the research project planning, aims and objectives, evidence and findings, validity, reliability, benefits, difficulties, conclusion(s)

Future consideration: significance of research investigation; application of research results; implications; limitations of the investigation; improvements; recommendations for the future, areas for future research

4 **Be able to present the research outcomes**

Format: professional delivery format appropriate to the audience; use of appropriate media

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Understand how to formulate a research specification	1.1 formulate and record possible research project outline specifications 1.2 identify the factors that contribute to the process of research project selection 1.3 undertake a critical review of key references 1.4 produce a research project specification 1.5 provide an appropriate plan and procedures for the agreed research specification
LO2 Be able to implement the research project within agreed procedures and to specification	2.1 match resources efficiently to the research question or hypothesis 2.2 undertake the proposed research investigation in accordance with the agreed specification and procedures 2.3 record and collate relevant data where appropriate
LO3 Be able to evaluate the research outcomes	3.1 use appropriate research evaluation techniques 3.2 interpret and analyse the results in terms of the original research specification 3.3 make recommendations and justify areas for further consideration
LO4 Be able to present the research outcomes	4.1 use an agreed format and appropriate media to present the outcomes of the research to an audience.

Guidance

Links

This unit may be linked to single or several units in the programme, depending on the research topic and the context of their area of learning.

The unit can also be linked to the SEMTA Level 4 National Occupational Standards in Engineering Management, particularly:

- Unit 4.5: Identify and Define Areas of Engineering Research
- Unit 4.6: Develop a Research Methodology for Engineering
- Unit 4.8: Undertake Engineering Research
- Unit 4.9: Evaluate the Results of Engineering Research.

Essential requirements

Tutor will need to establish the availability of resources to support the independent study before allowing the learner to proceed with the proposal.

Employer engagement and vocational contexts

Centres should try to establish relationships with appropriate organisations in order to bring realism and relevance to the research project.

Unit 29: Work-based Experience

Unit code: D/601/0998

Level: 5

Credit value: 15

Aim

This unit aims to enable learners to experience the scope and depth of learning which may take place in a work-based context by planning, monitoring and evaluating the work experience.

Unit abstract

A significant amount of learning can be achieved by carrying out practical activities in a workplace. Learning may be enhanced by taking a more formal approach to work-based activities – by planning, carrying out the activities and reflecting on the benefits of the activities to the business and to the learner.

This unit is designed to allow flexibility of study for part-time and full-time learners. It is expected that learners will be supervised in the workplace in addition to the supervision provided by their academic supervisor.

Learners will have the opportunity, supported by their supervisors, to negotiate and perform activities which will allow them to fulfil the assessment criteria for this unit. They will recognise the scope of what they have achieved by recording evidence from carrying out the activities. They will also gain maximum benefit by reflection on and evaluation of the work they undertake.

Learning outcomes

On successful completion of this unit a learner will:

1 Be able to negotiate industry experience

2 Understand the specific requirements of the placement

3 Be able to undertake work experience as identified

4 Be able to monitor and evaluate own performance and learning.

Unit content

1 **Be able to negotiate industry experience**

Suitable organisation and location: types of establishments for placement eg industry-related work for a client brief at college, existing work environment, different departments within current employer's business

Negotiation: methods of contacting organisations; methods of undertaking negotiations

Nature of duties: type of undertaking eg routine duties and tasks, project work, development of new procedures/protocol

Supervisors: roles and responsibilities of academic and industrial mentors

Expectations of learning: aims eg proficiency in new tasks and procedures, time-management and problem solving skills, reflection, discuss progress with others, teamwork

Business constraints: consideration of possible limitations eg need to be fully trained, adherence to quality systems, health and safety considerations, supervision time, workload, customer satisfaction, limited staffing, cost of materials

2 **Understand the specific requirements of the placement**

Tasks: details of activities eg specific hourly, daily, weekly routine and non-routine tasks; breakdown of a project into stages; new procedures/protocol

Prioritise: reasons for rationalisation of the order of tasks; methods of prioritising work

Plan for the work experience: methods used to develop detailed plan with schedule of tasks, proposed dates for reviews, expected input from supervisors

Benefits to organisation and learner: advantages to business eg allowing more routine tasks to be carried out, allowing procedures/techniques to be developed, increasing responsiveness, identifying cost saving measures; advantages to learner eg understanding how a business operates, understanding importance of teamwork, learning new techniques, development of problem-solving and time-management skills

3 **Be able to undertake work experience as identified**

Carry out the planned activities: realisation eg carrying out tasks and project work according to relevant legislation, training and codes of practice; developing new procedures or protocol

Record activities in the appropriate manner: systematic and appropriate recording of relevant activities eg logbook, diary, portfolio, spreadsheets, data bases; list of resources

Revise the initial plan as required: methods used to review activities at the appropriate time to see if they meet requirements, make alterations as needed

4 **Be able to monitor and evaluate own performance and learning**

Evaluation of the quality of the work undertaken: meeting industry standards and evaluating own performance against original proposal; comments/testimony from supervisors

Account of learning during the work experience: details of experience gained eg new procedures, interpersonal skills, time-management, problem-solving, teamwork; details of evidence eg portfolio of evidence, scientific report, management report

Recommendations on how the learning experience could have been enhanced: alternative ideas eg different location, different brief, different time period, more/less support, better time-management, better preparation

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Be able to negotiate industry experience	1.1 research and evaluate suitable organisations that could provide industry experience 1.2 negotiate with work and academic supervisors a proposal for the work experience 1.3 recognise the business constraints on the work experience offered
LO2 Understand the specific requirements of the placement	2.1 agree and prioritise the tasks and responsibilities involved in the work experience 2.2 produce a plan for the work experience 2.3 analyse the benefits of the proposed activities to the business and the learner
LO3 Be able to undertake work experience as identified	3.1 fulfil specified requirements of placement conforming to all related codes of practice 3.2 produce systematic records of work undertaken 3.3 revise the initial plan as required 3.4 make suggestions for improvement and review these with appropriate supervisor
LO4 Be able to monitor and evaluate own performance and learning	4.1 monitor progress against original proposal 4.2 evaluate the quality of own performance 4.3 analyse the learning which has taken place during the work experience using suitable reflections 4.4 make recommendations on how the experience could have been enhanced.

Guidance

Links

This unit has possible links with all units in the programme, especially the *Personal and Professional Development* and *Employability Skills* units.

Essential requirements

Given the work-based nature of this unit, the majority of resources will be those available to the learner in the workplace. The work will normally be planned to be achievable within the resource constraints of the employer. Therefore knowledge of company structures and daily routines and expectations are essential. Learners will also need access to a wide range of research facilities including careers library and/or careers services.

Tutor support and guidance are essential. Learners should remain in touch with tutors during the work-experience – email is often the best way but some colleges may have access to a virtual learning environment where learners can share information and experiences with each other and the tutor.

Employer engagement and vocational contexts

Delivery of this unit depends on centres establishing strong links with employers who can offer work-based placements.

Unit 30: Quality Assurance and Management

Unit code:	D/601/1486
Level:	5
Credit value:	15

Aim

This unit will develop learners’ knowledge and understanding of the principles and applications of quality management.

Unit abstract

In this unit learners will investigate total quality management (TQM) and develop an understanding of the key factors that underpin quality assurance (QA) techniques. The unit also introduces learners to the application of quality control (QC) techniques. The basic principles of total quality management will include management structures and TQM techniques. Learners will also develop an understanding of the key factors, internal and external controls and cost implications that underpin quality assurance techniques. Finally, the unit introduces the application of quality control techniques, process capability and software packages to support the processes.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand how total quality management (TQM) systems operate

2 Know the key factors of quality assurance (QA) techniques

3 Be able to apply quality control (QC) techniques.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017 © Pearson Education Limited 2017

Unit content

1 Understand how total quality management (TQM) systems operate

Principles of TQM: continuous improvement; total company commitment; quality strategy; management of change; focus eg internal and external customers, products/services, processes and people, fit-for-purpose; leadership; motivation and training; applicable supporting theories eg Deming, Juran, Crosby, Ishikawa

Management structures: organisational structures and responsibilities; quality improvement methods eg quality improvement teams and teamwork, quality circles/Kaizen teams; operational theory eg organisational culture, strategy, vision, mission, values and key issues; barriers to TQM eg lack of commitment, fear of change/responsibility, immediacy of pay-off, cost of TQM

TQM techniques: use of tools eg process flow charts, tally charts, Pareto analysis, cause and effect analysis, hazard analysis-critical control points, statistical process control SPC, benchmarking; methods eg brainstorming, team building, appraisal, training and development, mentoring; compliance to standards; procedures and manuals; impact of organisational factors eg leadership, communications, performance indicators and objectives

2 Know the key factors of quality assurance (QA) techniques

Key factors: procedures; quality manuals; parameters eg fitness-for-purpose, customer satisfaction, cost effectiveness, compliance with standards; standards organisation and documentation charts; communication; feedback; legislation

Control purposes: internal and external quality audits eg trace ability, compliance, statistical methods, planned maintenance, condition monitoring

Costing: quality vs productivity; cost centres; allocation of overheads; maintenance and downtime cost

3 Be able to apply quality control (QC) techniques

Quality control techniques: inventory control eg just-in-time (JIT), kanban, material requirements planning (MRP); statistical process control eg frequency distribution, mean range, standard deviation, control charts, calculation of warning and action limits; acceptance sampling eg producer’s and consumer’s risk, sampling plans, plotting and interpretation of an operating characteristic curve

Process capability: relationship between specification limits and control chart limits; modified limits; relative precision index

Software packages: eg quality audit procedures, vendor rating, cause and effect analysis, Pareto analysis

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Understand how total quality management (TQM) systems operate	1.1 explain the principles of TQM in relation to a specific application 1.2 evaluate management structures that can lead to an effective quality organisation 1.3 analyse the application of TQM techniques in an organisation
LO2 Know the key factors of quality assurance (QA) techniques	2.1 identify the key factors necessary for the implementation of a QA system within a given process 2.2 interpret a given internal and external quality audit for control purposes 2.3 describe the factors affecting costing
LO3 Be able to apply quality control (QC) techniques	3.1 report on the applications of quality control techniques 3.2 apply quality control techniques to determine process capability 3.3 use software packages for data collection and analysis.

Guidance

Links

This unit has links with *Unit 7: Business Management Techniques* and *Unit 3: Project Design, Implementation and Evaluation*.

The unit can also be linked to the SEMTA Level 4 National Occupational Standards in Engineering Management, particularly Unit 4.29: Implement Quality Assurance Methods and Procedures.

Essential requirements

Centres will need to provide simulated or actual examples for the application of methods used to install, monitor and control the quality of both products/services and their associated processes.

Employer engagement and vocational contexts

Industrial visits, work placements or employment could provide access to additional resource facilities and reinforce relevance. Wherever possible, learners should be given the opportunity to observe quality operations through industry visits. Equally, the work-based experiences of the learners should be used to illustrate applications of theory in practice.

Unit 31: Value Management

Unit code: A/601/1477

Level: 5

Credit value: 15

Aim

This unit aims to develop the skills and knowledge needed to analyse products and parts in order to improve value.

Unit abstract

This unit will provide learners with knowledge of the principles, methodologies and techniques that are used in analysing and selecting parts for improvement. This includes competencies required for value engineering and value analysis.

Learners will develop an understanding of Pareto analysis and how manufactured products can be identified as part families using a range of criteria. They will also consider total cost models and supply chain maps and their use with specific products or processes. Finally, learners will explore and develop their understanding of how to develop alternatives and detailed proposals that will improve the value of a product or process.

Learning outcomes

On successful completion of this unit a learner will:

1 Be able to carry out a Pareto analysis

2 Be able to produce part families using a range of criteria

3 Be able to produce a total cost model and supply chain map for a product or process

4 Be able to produce a detailed proposal from the findings of value management activities.

Unit content

1 **Be able to carry out a Pareto analysis**

Pareto analysis: 80 – 20 rule; ABC analysis; required information; data on usage (frequency); data on costs eg contribution, profit; annual usage value (AUV); methods of presentation eg bar graphs, histograms, Pareto curve

Criteria: customer schedules eg volume; cost of producing the part; profit for each part (as a percentage); manufacturing lead time; quality eg scrap, non-conformance percentage; process/manufacturing route

2 **Be able to produce part families using a range of criteria**

Part families: those that can be grouped together by a range of criteria; family definitions eg low cycle and high volume, high cycle time with low volume; use of bill of materials; part numbering systems eg Brisch, Optiz

Criteria: part shape; part size; material used to manufacture the part; manufacturing process; other features eg number of holes, number of shoulders, level of tolerance

3 **Be able to produce a total cost model and supply chain map for a product or process**

Total cost model: showing costs related to function; identification of value adding activities; identification of non-value adding activities

Supply chain map: showing costs related to function; aligned to Porter's Value Chain

4 **Be able to produce a detailed proposal from the findings of value management activities**

Detailed proposal: presenting findings from value management activities; proposals identifying the non-value added activities and indicates alternatives, prioritises and ranks alternatives, including a risk assessment of the alternatives; identifies the most appropriate alternatives; proves costing recommendations for management approval; identifies expected benefits

Value management activities: analysing the function of the product or process; non-value added activities; suggesting alternatives; performance related tools; cost of function calculations; Function Analysis System Technique (FAST) diagramming and value trees; decision making and creativity techniques eg brainstorming

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Be able to carry out a Pareto analysis	1.1 carry out a Pareto analysis against at least four criteria 1.2 describe what information will be required to conduct a Pareto analysis 1.3 describe the principles and process of Pareto analysis
LO2 Be able to produce part families using a range of criteria	2.1 produce part families from a given set of parts and a range of bill of materials 2.2 describe a part numbering system which would be helpful for putting parts into families
LO3 Be able to produce a total cost model and supply chain map for a product or process	3.1 produce a total cost model for a product or process 3.2 produce a supply chain map for a product or process 3.3 show how costs are related to functions and align these to Porter's Value Chain model
LO4 Be able to produce a detailed proposal from the findings of value management activities	4.1 develop and produce a detailed proposal following the use of value management activities 4.2 justify appropriate alternatives produced from the use of value management activities.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017 © Pearson Education Limited 2017

Guidance

Links

This unit is designed to stand alone but has links with *Unit 17: Business Improvement Techniques* and *Unit 20: Quality and Business Improvement.*

This unit can be linked with the SEMTA Level 4 National Occupational Standards in Business Improvement Techniques, particularly Unit 17: Applying Value Management (Value Engineering and Value Analysis).

Essential requirements

There are no essential requirements for this unit.

Employer engagement and vocational contexts

Liaison with industry should be encouraged in order to develop a valuable, relevant and alternative resource facility.

Unit 32: Industrial Robot Technology

Unit code: H/601/1473

Level: 5

Credit value: 15

Aim

This unit will develop learners' understanding of robots and the skills needed to program them for a range of industrial applications.

Unit abstract

Industrial robots have a wide range of applications, especially in the manufacturing and engineering sectors. This unit will develop learners' understanding of the key elements of industrial robots and how they are linked together as a system – manipulator, control and intelligence and sources of system errors. Learners will then develop and apply the skills used to program robots for industrial tasks (for example welding, assembly, machining, etc), and investigate the various programming methods and facilities that are available. Finally, the unit covers the design of an efficient, safe robot cell, and the factors that must be taken into account when selecting, installing and operating industrial robots. This should also include the economic and ethical issues that surround the introduction of robot technology.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand the key elements of industrial robots

2 Be able to program an industrial robot

3 Be able to design a robot cell and plan its implementation.

Unit content

1 **Understand the key elements of industrial robots**

Manipulator elements: electrical and fluid drive systems eg harmonic, cycloidal, shaft, rod, screw, belt, chain; sensors eg absolute and incremental encoders, potentiometers, resolvers, tachometers; brakes; counterbalance devices

Control elements: CPU; system and user memory; interface modules; power modules

Intelligence: relating to proximity, range, position, force, temperature, sound and gas

Sources of error or malfunction: environmental contamination eg smoke, arc-flash, dirt, fluids, heat; parallax; wear; data corruption; accessibility; sensitivity; accuracy; design

2 **Be able to program an industrial robot**

Programming methods: task programming; manual data input; teach programming; explicit programming; goal-directed programming

Facilities: conditional loops; datum shifts; location shifts; interrupts; peripheral communications; TCP offsets; canned cycles; macros

Industrial tasks: eg welding; assembly; machining; gluing; surface coating; machine loading

Setting up and executing the program: program/location input; start-up inter-locking; program testing; fine-tuning; automatic operation

3 **Be able to design a robot cell and plan its implementation**

Design parameters: layout; cycle times; control; accessibility; error detection; component specification; protection of the robot and peripherals, future developments; hazard analysis eg human, robot design, robot operation, workplace layout, hardware failure, control system failure, control system malfunction, software failure, external equipment failure, external sensor failure; guarding; fencing; intrusion monitoring; safe system of work; restriction mechanisms

Selection criteria: accuracy; repeatability; velocity; range; operation cycle time; load-carrying capacity; life expectancy; reliability; maintenance requirements; control and play-back; cost; memory; fitness for purpose; working envelope

Design: station configuration; parts presentation; fixtures; parts recognition; sensors; cell services; safety interlocks; end effector design; flexibility

Implementation factors: company familiarisation; planning; robot manufacturer back-up; economic analysis and ethical implications; installations scheduling; training

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Understand the key elements of industrial robots	1.1 analyse the key elements of a robot manipulator and their principles of operation 1.2 describe the main control elements of a robot system and explain their functions 1.3 describe the devices and methods used to improve the intelligence of a robot 1.4 investigate the possible sources of error or malfunction in an industrial robot system
LO2 Be able to program an industrial robot	2.1 describe common programming methods 2.2 describe the facilities available in a structured robot program 2.3 generate a robot program to simulate an industrial task using a structured technical language 2.4 set up the robot and execute the program so that the robot functions safely and efficiently
LO3 Be able to design a robot cell and plan its implementation	3.1 identify and evaluate the parameters which relate to the design of an efficient and safe robot cell 3.2 describe the criteria which must be considered in the selection of a robot for an industrial application 3.3 design a robot cell for an industrial application 3.4 describe the factors which must be considered in the implementation of a robot cell.

Guidance

Links

There are no links for this unit.

Essential requirements

Centres delivering this unit must be equipped with, or have access to, industrial-standard robots and programming facilities.

Employer engagement and vocational contexts

Visits to industrial installations will be of value to reinforce learning activities and enable the learner to appreciate the scope of and impact that robot technology can have in an industrial setting.

Unit 33: Workplace Study and Ergonomics

Unit code: D/601/1472

Level: 5

Credit value: 15

Aim

This unit will develop learners' ability to identify and carry out productivity measurement and improvement, ergonomic and plant layout design and work measurement and method study.

Unit abstract

This unit provides an opportunity for learners to apply several lean manufacturing techniques commonly used to identify and eliminate waste. Learners should have the opportunity to see skills and techniques at work in real engineering/manufacturing environments.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand productivity measurement techniques and the effect of a range of improvement methods

2 Understand the features of work measurement and method study techniques

3 Be able to assess the ergonomic and layout planning features of workstation and manufacturing operations design

4 Be able to select and apply appropriate industrial engineering techniques to a given engineering/manufacturing situation.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017 © Pearson Education Limited 2017

Unit content

1 **Understand productivity measurement techniques and the effect of a range of improvement methods**

Productivity measurement: methods of measuring physical factors – labour, materials and equipment; single factor and integrated productivity measurement, critical analysis techniques including cost benefit analysis and force field analysis; (evaluation may include graphical representations, statistical representations, fitness for purpose considerations and recognition of short-term and long-term effects); quality, cost, delivery (QCD) metrics, value stream mapping (VSM), process mapping

Productivity improvement: reduction in unit cost of manufacture by labour, product, materials, production level or machine automation, uses of new technology, efficient manual operation – use of work-study, job design, layout and ergonomic design, total quality management methods, waste of resources eg energy, human, materials; reduction/elimination of the
'8 wastes'; standardised operations and their relevant forms, takt time analysis and production smoothing, change-over analysis (SMED)

2 **Understand the features of work measurement and method study techniques**

Work measurement: direct work measurement – time study and activity sampling; indirect work measurement – synthetic timing; predetermined motion time systems (PMTS) – methods time measurement (MTM); computer-based programs; primary standard data; analytical estimating

Method study: job selection; recording methods and procedures; method description; development of improved method; definition of new method and installation and maintenance

Work measurement and study: chart format; simple comparisons; critical analysis; ranking techniques; technique application description; fitness for purpose

3 **Bea able to assess the ergonomic and layout planning features of workstation and manufacturing operations design**

Ergonomic features: features of design including worker machine controls, environmental factors, anthropometrical data used in the design of workstations, special features for VDU operators, role of health and safety

Layout planning features: features of design, including types of layout, operation sequence analysis, layout planning procedures and method, dedicated computer software, principles of motion economy

Layout design: workstation design features such as characteristics of the operator, interaction between workspace and the operator eg posture, reach, desk/machine size, adjacent machinery, interaction between the environment and the operator

Assess: develop criteria for good layout of workstation and manufacturing operations, consider flexibility, co-ordination, volume, visibility, accessibility, distance, handling, discomfort, safety, security, material flow, part identification, Poka yoke and Jidoka techniques

4 **Be able to select and apply appropriate industrial engineering techniques to a given engineering/manufacturing situation**

Engineering/manufacturing situation: collect information and data on current company aims (eg current productivity, measurement, processes, process flow, scheduling, materials, equipment, labour, layout, ergonomic features of labour force and equipment operation); present evidence in a relevant form eg graphs, statistics, manuals, diagrams, recorded interviews, recorded observations, computer programs

Engineering techniques: selection and application of techniques eg productivity measurement, productivity improvement, method study, work measurement, ergonomic design, layout planning; formulate a plan of action, appraise the feasibility of the techniques with reference to the engineering/manufacturing situation, make simple comparisons and use decision-making techniques eg consider fitness for purpose, long-term and short-term effects on the engineering/manufacturing situation; record and justify any changes to current engineering/manufacturing situation; present findings using relevant methods eg use of graphs, statistics, flow diagrams, layouts, computer programs, graphical techniques, video, file, written reports and discussion; use of appropriate lean manufacturing techniques eg use of QCD metrics, VSM, process mapping, takt time analysis, production smoothing, pull systems, SMED, visual management techniques

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Understand productivity measurement techniques and the effect of a range of improvement methods	1.1 describe techniques of productivity measurement 1.2 analyse and evaluate the usefulness of the range of productivity measurement techniques 1.3 describe methods of productivity improvement 1.4 analyse and evaluate the effects of the range of productivity improvement methods
LO2 Understand the features of work measurement and method study techniques	2.1 explain how work study comprises of work measurement and method study techniques 2.2 describe work measurement and method study techniques 2.3 analyse a range of work measurement and work study techniques used for a given situation
LO3 Be able to assess the ergonomic and layout planning features of workstation and manufacturing operations design	3.1 describe ergonomic and layout planning features of workstation and manufacturing operations design 3.2 assess these features to develop criteria for good layout design
LO4 Be able to select and apply appropriate industrial engineering techniques to a given engineering/ manufacturing situation	4.1 gather and present appropriate information from a given engineering/manufacturing situation 4.2 select industrial engineering techniques appropriate to a given engineering/manufacturing situation 4.3 apply industrial engineering techniques to a given engineering/manufacturing situation.

Guidance

Links

This unit can be linked with a wide range of engineering/manufacturing specialist units including *Unit 9: Manufacturing Planning and Scheduling Principles*, *Unit 10: Manufacturing Process*, *Unit 30: Quality Assurance and Management*, *Unit 20: Quality and Business Improvement* and *Unit 31: Value Management*.

Essential requirements

Many of the techniques involved in industrial engineering use specialist software that may prove expensive. In such cases, centres will need to ensure that learners can view an industrial demonstration of such software at the least.

Employer engagement and vocational contexts

Industrial visits, work placements or employment could provide access to additional resource facilities and reinforce relevance.

Unit 34: Integrated Logistical Support Management

Unit code:	Y/601/1468
Level:	5
Credit value:	15

Aim

The aim of this unit is to develop the knowledge and skills needed to develop and apply an integrated logistics support programme.

Unit abstract

This unit will enable learners to develop and implement an integrated logistics support programme. Learners will look at the features of implementation and produce a structured representation of all tasks needed for the development and implementation stages.

The first learning outcome will enable learners to analyse and develop an integrated logistic (ILS) support programme. They will then go on to produce a work breakdown structure for the tasks required to achieve the ILS requirements.

Learners will also develop the techniques used to monitor an ILS and will apply risk management techniques to identify potential risks and recommend ways to mitigate them.

Learning outcomes

On successful completion of this unit a learner will:

1 Be able to develop an integrated logistic support (ILS) programme

2 Be able to produce a work breakdown structure (WBS) for the tasks required to achieve an ILS programme

3 Be able to use techniques to monitor an ILS programme and a system of quality assurance

4 Be able to apply risk management techniques and recommend mitigating measures against an ILS programme.

Unit content

1 **Be able to develop an integrated logistic support (ILS) programme**

Integrated logistic support (ILS) programme: agreeing with customers the levels of accuracy, programme and schedules; preparing and structuring the programmes and schedules; identification of dependencies and restraints between starts and ends of activities; uncertainty; identification of demand-led resource allocation; use of simple computer-based planning tools

2 **Be able to produce a work breakdown structure (WBS) for the tasks required to achieve an ILS programme**

Key factors: confirming the ILS status; developing interfaces to other specialist areas; identifying deliverables; establishing procedures and responsibilities

Work breakdown structure (WBS): a structured representation of all tasks required to achieve the ILS requirements; WBS represented as charts, trees, lists, tables and can include ILS tasks, ILS management and ILS dependencies

3 **Be able to use techniques to monitor an ILS programme and a system of quality assurance**

Quality assurance system: a system to maintain standards to a previously agreed level; quality assurance achieved through document control, configuration management, document format and agreed standards

Monitoring techniques: the regular checking of specific activities or outcomes to ensure that they are being achieved according to requirements; monitoring eg observation, data collection, sampling, continuous, periodic, on demand, random, scheduled, formal, informal

4 **Be able to apply risk management techniques and recommend mitigating measures against an ILS programme**

Techniques of risk management: risk identification eg identifying sources of information to assemble risk data, risk register, maintaining risk records; risk assessment and evaluation eg assessing likelihood and severity, evaluating the impact; risk reduction; risk review

Measures of mitigation: undertaking the appropriate course of action including revisions, improvements, enhancements and reduction; compare different measures of mitigation in relationship to an ILS programme

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Be able to develop an integrated logistic support (ILS) programme	1.1 prepare an ILS programme in the form of accuracy required, programme and schedules 1.2 describe dependencies, restraints and uncertainties in an ILS programme 1.3 identify resources required for an ILS programme
LO2 Be able to produce a work breakdown structure (WBS) for the tasks required to achieve an ILS programme	2.1 describe the key factors influencing the implementation of an ILS programme 2.2 produce and present a work breakdown structure for the tasks required to achieve ILS programme requirements
LO3 Be able to use techniques to monitor an ILS programme and a system of quality assurance	3.1 produce a report to show the progress made and the quality assurance systems used to assure quality in an ILS programme 3.2 justify the use of monitoring techniques applied and quality assurance systems used to measure progress for an ILS programme
LO4 Be able to apply risk management techniques and recommend mitigating measures against an ILS programme	4.1 describe and use techniques of risk management when applied to an ILS programme 4.2 compare different measures of mitigation in relationship to an ILS programme.

Guidance

Links

This unit has links with *Unit 7: Business Management Techniques for Engineers* and *Unit 30: Quality Assurance and Management*.

Essential requirements

Centres will need to provide simulated or actual examples for the application of an ILS programme.

Employer engagement and vocational contexts

Industrial visits, work placements or employment could provide access to additional resource facilities and reinforce relevance.

Unit 35: Further Analytical Methods for Engineers

Unit code: J/601/1465

Level: 5

Credit value: 15

Aim

This unit aims to further develop the analytical knowledge and techniques necessary to analyse and solve a variety of engineering situations and problems.

Unit abstract

This unit has been designed to enable learners to use number systems, graphical and numerical methods, vectors, matrices and ordinary differential equations to analyse, model and solve realistic engineering problems.

Learners will use estimation techniques and error arithmetic to establish realistic results from experiments and general laboratory work. They will then consider the conversion of number systems from one base to another and the application of the binary number system to logic circuits. Complex numbers and their application to the solution of engineering problems are also studied.

Learners will look at the use of graphical techniques together with various methods of numerical integration (for example Simpson's rules) and estimation (for example Newton-Raphson). They will then go on to analyse and model engineering situations using vector geometry and matrix methods.

Finally, learners will study both first and second order differential equations and their application to a variety of engineering situations dependant upon the learner's chosen discipline.

Learning outcomes

On successful completion of this unit a learner will:

1 Be able to analyse and model engineering situations and solve problems using number systems

2 Be able to analyse and model engineering situations and solve problems using graphical and numerical methods

3 Be able to analyse and model engineering situations and solve problems using vector geometry and matrix methods

4 Be able to analyse and model engineering situations and solve problems using ordinary differential equations.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017 © Pearson Education Limited 2017

Unit content

1 **Be able to analyse and model engineering situations and solve problems using number systems**

Error arithmetic: significant figures and estimation techniques; error arithmetic operations; systematic and random errors; application to experimentation and general laboratory work

Number systems: natural, integer, rational, reals, dinary, binary, octal and hexadecimal number systems; conversion from dinary to numbers of other bases and vice versa; two-state logic systems, binary numbers and logic gates, logic gate tables, application to logic circuits

Complex numbers: real and imaginary parts of complex numbers, complex number notation; Cartesian and polar forms; modulus, argument and complex conjugate; addition, subtraction, multiplication and division of Cartesian and polar forms; use of Argand diagrams; powers and roots and the use of de Moivre's theorem

Engineering applications: applications eg electric circuit analysis, phasors, transmission lines, information and energy control systems

2 **Be able to analyse and model engineering situations and solve problems using graphical and numerical methods**

Graphical techniques: Cartesian and polar co-ordinate systems and representation of complex number operations; vector representation; standard curves; asymptotes; systematic curve sketching; curve fitting; irregular areas and mean values of wave forms; use of phasor and Argand diagrams; application to engineering situations

Numerical integral: determine the integral of functions using mid-ordinate; trapezoidal and Simpson's rules

Numerical estimation methods: method of bisection; Newton-Raphson iteration method; estimates of scientific functions

3 **Be able to analyse and model engineering situations and solve problems using vector geometry and matrix methods**

Vector notation and operations: Cartesian co-ordinates and unit vectors; types of vector and vector representation; addition and subtraction; multiplication by a scalar; graphical methods

Matrix operations and vectors: carry out a range of matrix operations eg vectors in matrix form, square and rectangular matrices, row and column vectors, significance of the determinant, determinant for 2x2 matrix, the inverse of a 2x2 matrix; use Gaussian elimination to solve systems of linear equations (up to 3x3)

Vector geometry: determine scalar product, vector product, angle between two vectors, equation of a line, norm of a vector, dot and cross products; apply vector geometry to the solution of engineering problems eg velocity vector and mechanisms, acceleration vector and mechanisms, forces in static frameworks and structures, evaluation of static joint structures using dot product, phasors

4 **Be able to analyse and model engineering situations and solve problems using ordinary differential equations**

First order differential equations: engineering use; separation of variables; integrating factor method, complementary function and particular integral

Numerical methods for first order differential equations: need for numerical solution; Euler's method; improved Euler method; Taylor series method

Application of first order differential equations: applications eg RC and RL electric circuits, time constants, motion with constant and variable acceleration, Fourier equation for heat transfer, Newton's laws of cooling, charge and discharge of electrical capacitors, complex stress and strain, metrology problems

Second order differential equations: engineering use; arbitrary constants; homogeneous and non-homogeneous linear second order equations

Application of second order differential equations: applications eg RLC series and parallel circuits, undamped and damped mechanical oscillations, fluid systems, flight control laws, mass-spring-damper systems, translational and rotational motion systems, thermodynamic systems, information and energy control systems, heat transfer, automatic control systems, stress and strain, torsion, shells, beam theory

Engineering situations: applications eg heat transfer, Newton's laws, growth and decay, mechanical systems, electrical systems, electronics, design, fluid systems, thermodynamics, control, statics, dynamics, energy systems, aerodynamics, vehicle systems, transmission and communication systems

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Be able to analyse and model engineering situations and solve problems using number systems	1.1 use estimation techniques and error arithmetic to establish realistic results from experiment 1.2 convert number systems from one base to another, and apply the binary number system to logic circuits 1.3 perform arithmetic operations using complex numbers in Cartesian and polar form 1.4 determine the powers and roots of complex numbers using de Moivre's theorem 1.5 apply complex number theory to the solution of engineering problems when appropriate
LO2 Be able to analyse and model engineering situations and solve problems using graphical and numerical methods	2.1 draw graphs involving algebraic, trigonometric and logarithmic data from a variety of scientific and engineering sources, and determine realistic estimates for variables using graphical estimation techniques 2.2 make estimates and determine engineering parameters from graphs, diagrams, charts and data tables 2.3 determine the numerical integral of scientific and engineering functions 2.4 estimate values for scientific and engineering functions using iterative techniques
LO3 Be able to analyse and model engineering situations and solve problems using vector geometry and matrix methods	3.1 represent force systems, motion parameters and waveforms as vectors and determine required engineering parameters using analytical and graphical methods 3.2 represent linear vector equations in matrix form and solve the system of linear equations using Gaussian elimination 3.3 use vector geometry to model and solve appropriate engineering problems

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO4 Be able to analyse and model engineering situations and solve problems using ordinary differential equations	4.1 analyse engineering problems and formulate mathematical models using first order differential equations 4.2 solve first order differential equations using analytical and numerical methods 4.3 analyse engineering problems and formulate mathematical models using second order differential equations 4.4 solve second order homogeneous and non-homogenous differential equations 4.5 apply first and second order differential equations to the solution of engineering situations.

Guidance

Links

This unit builds on and can be linked to *Unit 1: Analytical Methods for Engineers* and can provide a foundation for *Unit 59: Advanced Mathematics for Engineering*.

Essential requirements

There are no essential requirements for this unit.

Employer engagement and vocational contexts

This unit will benefit from centres establishing strong links with employers who can contribute to the delivery of teaching, work-based placements and/or detailed case study materials.

Unit 36: Statistical Process Control

Unit code: K/601/1460

Level: 5

Credit value: 15

Aim

This unit will enable learners to apply relevant statistical techniques used in process quality control and to evaluate a process against a given specification.

Unit abstract

This unit takes the learner through the statistical techniques used in process control, variables inspection and attribute inspection. It covers the handling of data and the use of process control charts. This will lead learners into the study of process capability and identification of types of variation within a process.

Control charts will be seen as a graphic aid for the detection of quality variations in output. Emphasis is given to their online monitoring function, which provides early warning of deviations from specifications.

The importance of process capability analysis in production planning, processing method, modification and maintenance will also be stressed.

Learning outcomes

On successful completion of this unit a learner will:

1. Understand the basic types, variations and characteristics of statistical techniques used in process control
2. Be able to select data, construct process control charts and initiate a control program for a specified application
3. Be able to evaluate process capability against a given product or component quality requirement using modified control chart limits
4. Be able to analyse types of variation within a process and record information on that variation.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017 © Pearson Education Limited 2017

Unit content

1 **Understand the basic types, variations and characteristics of statistical techniques used in process control**

Basic type: evaluation of basic types – variables inspection eg that concerned with precision measurements of dimensions or other critical characteristics such as weight; attribute inspection eg based on a binary rating (accept – reject); the relative cost and type of equipment involved in the inspection process

Variation: all processes subject to some degree of natural variability that can have a cumulative effect on quality of output eg worn bearings, slides, vibration; these are a function of the accuracy of the process and hence relate to the design specification requirement; assignable causes tend to produce large variations and are traceable to a specific reason eg errors in tool setting, tool wear, materials, operators

Characteristics: frequency, mean, standard deviation; control limits based on areas contained within specified standard deviation values

2 **Be able to select data, construct process control charts and initiate a control program for a specified application**

Sample data: variables eg weight, length, height, diameter; attributes eg length, diameter, weight, height, circuit boards, defects per unit area/length on paint or cloth; data should be grouped in tabular form and sample means; bulk mean and standard deviation values computed, using appropriate software; p and c charts

Limits: upper and lower control limits based on appropriate BS and ISO standards for all charts

3 **Be able to evaluate process capability against a given product or component quality requirement using modified control chart limits**

Modified control charts: should allow flexibility to accommodate long-term variation while maintaining control within the specified tolerance

Limits: distinction between specification limits and control chart limits, reduction of variability and its effect on range; high, medium and low precision in terms of standard deviation for a particular component or product should be used to determine the relative precision index for the process and hence its capability; *Cp* and *Cpk*

4 **Be able to analyse types of variation within a process and record information on that variation**

Types of variation: within the process; common cause; special cause

Recording variation: charts eg simple run, tally, bar, box plots time series, run; other information eg histograms, Pareto diagrams, stem and leaf plots

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Understand the basic types, variations and characteristics of statistical techniques used in process control	1.1 evaluate the two basic types of inspection used in sampling for process control 1.2 describe the significance of natural and assignable causes of variation 1.3 use selected data to construct frequency distribution and calculate mean, range and standard deviation 1.4 relate the characteristics of the normal curve to the distribution of the means of small samples
LO2 Be able to select data, construct process control charts and initiate a control program for a specified application	2.1 select and group sample data based on variable inspection and attributable inspection and calculate appropriate control chart limits 2.2 construct control charts for variables, rejects per unit and percentage defectives per batch 2.3 initiate a control program for a specified application
LO3 Be able to evaluate process capability against a given product or component quality requirement using modified control chart limits	3.1 describe process capability 3.2 investigate the purpose of modified control chart limits 3.3 evaluate processes against a given quality requirement
LO4 Be able to analyse types of variation within a process and record information on that variation	4.1 analyse a range of processes for types of variation 4.2 record information on variation from a process.

Guidance

Links

This unit may be delivered individually or as part of a wider project with other relevant production-based units.

The unit can also be linked to the SEMTA Level 4 National Occupational Standards in Business Improvement Techniques, particularly Unit 14: Carrying Out Statistical Process Control Procedures (SPC).

Essential requirements

There are no essential requirements for this unit.

Employer engagement and vocational contexts

Industry links could provide access to alternative resource facilities and learners who are not in work-based settings should have the opportunity to visit industrial organisations to gain knowledge and experience of process control and its function within the total quality system.

Unit 37: Management of Projects

Unit code: J/601/0302

Level: 4

Credit value: 15

Aim

This unit provides an understanding and experience of project management principles, methodologies, tools and techniques that may be used in industry and the public sector.

Unit abstract

The management of projects is a key element for successful scientific investigation of activities related to academic research, company research and development or consultancy.

Through this unit learners will develop an understanding of what constitutes a project and the role of a project manager. They will examine the criteria for the success or failure of a project, evaluate project management systems and review the elements involved in project termination and appraisal.

Learners will also understand the need for structured organisation within the project team, effective control and coordination and good leadership qualities in the project manager. They will be able to analyse and plan the activities needed to carry out the project, including how to set up a project, how to control and execute a project, and how to carry out project reviews using a specialist software package for project management. They will also appreciate how the project fits into the strategy or business plan of an organisation.

Learning outcomes

On completion of this unit a learner should:

1 Understand the principles of project management

2 Be able to plan a project in terms of organisation and people

3 Be able to manage project processes and procedures.

Unit content

1 **Understand the principles of project management**

Project management: project management and the role of the project manager eg management of change, understanding of project management system elements and their integration, management of multiple projects, project environment and the impact of external influences on projects; identification of the major project phases and why they are required; an understanding of the work in each phase; the nature of work in the lifecycles of projects in various industries

Success/failure criteria: the need to meet operational, time and cost criteria; define and measure success eg develop the project scope, product breakdown structure (PBS), work breakdown structure (WBS), project execution strategy and the role of the project team; consideration of investment appraisal eg use of discount cash flow (DCF) and net present value (NPV); benefit analysis and viability of projects; determine success/failure criteria; preparation of project definition report; acceptance tests

Project management systems: procedures and processes; knowledge of project information support (IS) systems; how to integrate human and material resources to achieve successful projects

Terminating the project: audit trails; punch lists; close-out reports

Post-project appraisals: comparison of project outcome with business objectives

2 **Be able to plan a project in terms of organisation and people**

Organisational structure: functional, project and matrix organisational structures eg consideration of cultural and environmental influences, organisational evolution during the project lifecycle; job descriptions and key roles eg the project sponsor, champion, manager, integrators; other participants eg the project owner, user, supporters, stakeholders

Roles and responsibilities: the need for monitoring and control eg preparation of project plans, planning, scheduling and resourcing techniques,

Control and co-ordination: use of work breakdown structures to develop monitoring and control systems, monitoring performance and progress measurement against established targets and plans; project reporting; change control procedures; the importance of cascading, communications briefing, instilling trust and confidence in others

Leadership requirements: stages of team development e.g. Belbin's team roles, motivation and the need for team building, project leadership styles and attributes; delegation of work and responsibility; techniques for dealing with conflict; negotiation skills; chair meetings

Human resources and requirements: calculation; specification; optimisation of human resource requirements; job descriptions

3 **Be able to manage project processes and procedures**

Project organisation: the product breakdown structure (PBS) and the work breakdown structure (WBS); project execution strategy and the organisation breakdown structure (OBS) eg preparation of organisation charts, task responsibility matrix, statement of work (SOW) for project tasks

Project management plans: the why, what, how, when, where and by whom of project management eg contract terms, document distribution schedules, procurement, establishing the baseline for the project

Scheduling techniques: relationship between schedules, OBS and WBS; bar charts; milestone schedules; network techniques; resourcing techniques; computer-based scheduling and resourcing packages; project progress measurement and reporting techniques; staff-hours earned value and progress 'S' curves; critical path analysis and reporting; milestone trending

Cost control techniques: cost breakdown structure eg types of project estimate, resources needed, estimating techniques, estimating accuracy, contingency and estimation, bid estimates, whole-life cost estimates, sources of information, cost information sensitivity, computer-based estimating; allocation of budgets to packages of work; committed costs; actual costs; cash flow; contingency management

Performance: cost performance analysis eg budgeted cost for work scheduled (BCWS) budgeted cost for work performed (BCWP); concept of earned value; actual cost of work performed (ACWP); cost performance indicators

Change control procedures: the need for formal control of changes e.g. project impact of changes, principles of change control and configuration management; changes to scope, specification, cost or schedule; change reviews and authorisation; the formation of project teams; project initiation and start-up procedures

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Understand the principles of project management	1.1 explain the principles of project management 1.2 discuss viability of projects with particular emphasis on the criteria for success/failure 1.3 explore principles behind project management systems and procedures 1.4 explain key elements involved in terminating projects and conducting post-project appraisals
LO2 Be able to plan a project in terms of organisation and people	2.1 plan the most appropriate organisational structure 2.2 discuss roles and responsibilities of participants within a project 2.3 carry out the control and co-ordination of a project 2.4 document project leadership requirements and qualities 2.5 plan specific human resources and requirements for a project
LO3 Be able to manage project processes and procedures	3.1 design the project organisation with reference to prepared project management plans 3.2 use project scheduling and cost control techniques 3.3 report the methods used to measure project performance 3.4 report project change control procedures 3.5 discuss the outcomes of the project and make recommendations.

Guidance

Links

This unit could be studied in parallel with, and complement, *Unit 3: Project Design, Implementation and Evaluation*, which could provide many of the skills necessary for the successful completion of this unit. This unit is also supported by *Unit 7: Business Management Techniques.*

Essential resources

Appropriate software packages will be needed to demonstrate project control and reporting techniques. Packages might include time and cost scheduling packages, documentation and procurement control packages, spreadsheet packages, graphic presentation packages.

Employer engagement and vocational contexts

Learners will benefit from visits to organisations that are in engaged in project work as a part of academic research, investigations and research for public bodies, company research and development or consultancy activities. An ideal context would be for the learner to manage a project that was of interest to a particular organisation.

Unit 38: Managing People in Engineering

Unit code: M/601/1458

Level: 5

Credit value: 15

Aim

This unit will develop learners' understanding of the methods, processes and procedures used when managing people in engineering.

Unit abstract

The unit will give learners an opportunity to examine the various practices, procedures and constraints that influence the management of people within a work environment. This will require learners to consider and explain the processes and procedures involved in the management of people, such as human resource planning, recruitment, selection and contracting. Learners will also investigate a range of working relationships in engineering settings and the lines of responsibility. Management and development of human resources are also covered with an examination of industrial relations and legislation.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand the processes and procedures involved in people management

2 Understand working relationships within an engineering context

3 Understand methods of managing and developing human resources

4 Understand industrial relations and legislation within an employment relationship.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017 © Pearson Education Limited 2017

Unit content

1 **Understand the processes and procedures involved in people management**

Workforce planning: estimating manpower requirements; the labour market; needs analysis and evaluation; recruitment and selection; training and development; cost implications; general employment environment eg market conditions, labour turnover, demographic issues, skills shortages, use of part-time and older employees

Recruitment and selection: job descriptions; personnel specifications; recruitment sources; advertising; relevant legislation eg equal opportunities, discrimination; interviewing techniques; selection tests eg psychometric, intelligence, personality; employment contract eg full/part-time, seasonal, sub-contracted, consultant, fractional posts, outworking; associated legislation

2 **Understand working relationships within an engineering context**

Working relationships: teams eg adhoc, organised, long-term, short-term; individuals; peers; hierarchical eg managerial, subordinate

Lines of authority and communication: within the organisation; within the team

Roles: operative; craft, supervisory; managerial

Objectives: induction; deployment and monitoring of employees; achieving organisation targets; supporting team members; encouraging individuals; creating a cohesive workforce; managing poor or ineffective performance; managing tensions and conflict

Managing sub-contractors: negotiating targets, deadlines and performance standards; monitoring and assessing performance; operating within constraints; meeting financial targets

3 **Understand methods of managing and developing human resources**

Employee motivation: theories; methods; employee involvement; motivating individuals/teams

Training: techniques eg induction, on- and off-the-job training, in-house, contracted-out; qualifications framework; current occupational standards; future needs

Reward systems: pay structures eg performance-related pay, incentive schemes, team rewards; employee benefits eg pensions, company share schemes, medical insurance, sickness benefit, promotions

Appraisal and development: schemes; management development; preparing employees for progression; matching organisational needs with employee potential

Benefits of training and development: for the individual eg motivation, pride, job satisfaction, job enrichment, job enlargement, external qualifications; for the organisation eg qualified staff, increase in skilled staff, improved results due to increase in quality, well-motivated staff, flexible staff

4 **Understand industrial relations and legislation within an employment relationship**

Contractual regulations: the employment contract; pay; hours; conditions; the right to trade union membership

Employment practices: disciplinary and grievance procedures eg employment tribunal systems, appeals, arbitration procedures; the role of trade unions; collective bargaining; the role of ACAS (Advisory, Conciliation and Arbitration Service); codes of practice; poaching staff

Termination of employment: types of dismissal eg unfair and constructive, redundancy, job restructuring; resignation; retirement

Employment legislation: UK and EU employment eg Sex Discrimination Act 1975, Race Relations Act 1976, Rehabilitation of Offenders Act 1974, Equal Pay Act 1970, implications of the working time regulation, Transfer of Undertakings (Protection of Employment) 2006, Employment Act 2002, legislation relating to harassment; disciplinary/grievance interviews; first aid requirements; disabled provisions; maternity/paternity issues; flexible employment practices eg job share, working from home

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Understand the processes and procedures involved in people management	1.1 explain how workforce planning is used to assess staffing requirements 1.2 analyse how the general employment environment affects effective workforce recruitment and selection 1.3 outline the processes and procedures carried out when recruiting and selecting personnel for a given engineering post
LO2 Understand working relationships within an engineering context	2.1 explain different working relationships within an engineering organisation 2.2 examine lines of authority within an engineering organisation 2.3 discuss roles and responsibilities of employees within an engineering organisation 2.4 review the relevance of objectives of working relationships within an engineering context 2.5 explain how sub-contractors can be managed
LO3 Understand methods of managing and developing human resources	3.1 explain the importance of employee motivation and involvement 3.2 evaluate a range of training techniques which are employed within an engineering organisation 3.3 explain the role of reward systems, appraisal and development schemes within an engineering organisation 3.4 explain the benefits of training and development to the organisation and the individual
LO4 Understand industrial relations and legislation within an employment relationship	4.1 describe contractual regulations of employment 4.2 justify the use of employment practices in an engineering organisation 4.3 explain the constraints imposed by legislation on termination of employment 4.4 examine and report on the main features of current employment legislation.

Guidance

Links

This unit can be linked with *Unit 7: Business Management Techniques for Engineers*.

Essential requirements

Learners will need access to relevant UK and EU legal and legislative reference material.

Employer engagement and vocational contexts

The delivery of this unit will benefit from centres establishing strong links with employers willing to contribute to the delivery of teaching, work-based placements and/or detailed case study materials.

Unit 39: Electronic Principles

Unit code: J/601/1448

Level: 5

Credit value: 15

Aim

This unit aims to further develop learners' understanding of analogue electronics and their applications across the engineering sector.

Unit abstract

In this unit, learners will examine the use of current manufacturers' data and support, apply current circuit analyses and design, implement and then test the created applications.

Although fault-finding skills are not the main emphasis of the unit they will form an integral part in the later development, in terms of testing.

Learning outcomes

On successful completion of this unit a learner will:

1 Be able to apply testing procedures for semiconductor devices and circuits

2 Understand the characteristics and operation of amplifier circuits

3 Understand the types and effects of feedback on circuit performance

4 Understand the operation and applications of sine wave oscillators.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017 © Pearson Education Limited 2017

Unit content

1 **Be able to apply testing procedures for semiconductor devices and circuits**

Circuits and testing: half and full wave rectifying; zener regulator; switching and amplifier circuits for transistors; IC voltage regulators instruments eg CRO, probes, signal generators, multi-meter, logic

Devices: semiconductor devices eg diodes (rectifier characteristics including forward/reverse bias modes, zener, LED, photodiode, thyristor, triac), transistors (bipolar, unipolar and field-effect, including characteristics and switch and amplifier modes), photo-transistors, opto-couplers, integrated circuits (741 operational amplifier applications including filters, comparators, power supplies and oscillators), IC voltage regulator, ‘specialist’ ICs (analogue and digital)

Literature: manufacturers’ specifications; manuals; characteristics; circuit diagrams and support (online and offline)

2 **Understand the characteristics and operation of amplifier circuits**

Amplifier characteristics: ideal (gain, bandwidth, input/output impedance, noise, thermal drift); common notation; DC/AC behaviour; op-amp basic circuits; limitations (DC, AC, non-linear, power); common applications; internal circuitry of 741 (differential, voltage and output amplifier)

Analyse operation and performance: use of quantitative methods; equivalent circuits; computer modelling; consideration of frequency response; voltage gain; bandwidth; output power; distortion; input and output impedance

Types and benefits of amplifier: power eg single-ended Class A, complementary symmetrical Class B, Class AB; tuned; small-signal; operational amplifiers eg inverting, non-inverting, voltage follower, differential, summing, integrator, differentiator, comparator, instrumentation, Schmitt trigger; active filters (high-pass, low-pass, band (pass, reject), notch)

Modify circuit designs: using manufacturers’ data; circuit calculations; to meet revised specifications using alternative components to achieve lower cost or to improve performance

3 **Understand the types and effects of feedback on circuit performance**

Types and effects of feedback: types eg voltage, current, series, shunt; effects eg closed loop gain of a system with feedback, feedback in single and multi-stage circuits

Circuit performance: effect of feedback on gain, bandwidth, distortion, noise, gain stability, input and output impedance

Circuits: single-stage transistor amplifier; operational amplifier

Investigate: circuit design and build, practical measurement; computer simulation

4 **Understand the operation and applications of sine wave oscillators**

Circuit requirements: circuit conditions eg $1-\beta A = 0$ at only one frequency, gain-phase relationship in the circuit; frequency determining elements

Build and evaluate: to a given specification a typical circuit configuration eg Wien Bridge, Twin-T, three-section R-C ladder, L-C coupled, transistor or operational amplifier

Specification: factors eg frequency, stability, frequency drift, distortion; need for amplitude stabilisation

Crystal oscillators: advantages of crystal controlled oscillator circuits eg frequency accuracy and stability; equivalent circuit of a quartz crystal; fundamental and overtone circuits

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017 © Pearson Education Limited 2017

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Be able to apply testing procedures for semiconductor devices and circuits	1.1 apply testing procedures to a range of semiconductor devices and circuits 1.2 use relevant literature for testing semiconductor devices and circuits
LO2 Understand the characteristics and operation of amplifier circuits	2.1 analyse the operation of different types of amplifier 2.2 evaluate the actual performance of different types of amplifier 2.3 compare the analysis with the measured results 2.4 modify circuit designs to meet revised specifications
LO3 Understand the types and effects of feedback on circuit performance	3.1 describe types of feedback and determine the effects on circuit performance when feedback is applied 3.2 design a circuit employing negative feedback 3.3 investigate the effects of applying feedback to single and multi-stage circuits
LO4 Understand the operation and applications of sine wave oscillators	4.1 describe the circuit conditions and the methods used to achieve sinusoidal oscillation 4.2 build and evaluate a sine wave oscillator to a given specification 4.3 explain the advantages of crystal-controlled oscillator circuits.

Guidance

Links

This unit may be linked to *Unit 1: Analytical Methods for Engineers* and *Unit 5: Electrical and Electronic Principles*.

Essential requirements

Centres must ensure that learners have access to appropriate laboratory test equipment (eg signal generators, oscilloscopes, digital frequency meters, audio power meters and test meters).

Employer engagement and vocational contexts

The delivery of this unit will benefit from centres establishing strong links with employers willing to contribute to the delivery of teaching, work-based placements and/or detailed case study materials.

Unit 40: Knowledge-based Systems and Techniques

Unit code:	A/601/1446
Level:	5
Credit value:	15

Aim

This unit will introduce learners to the concepts and techniques used in artificial intelligence and knowledge-based systems and develop an understanding of rule-based systems, fuzzy logic and artificial neural networks.

Unit abstract

The unit starts by introducing learners to knowledge bases and rule bases that are used extensively in expert systems, and at a much lower level are used for simple reasoning/logic operations. The concept of rule bases is extended to fuzzy operations and fuzzy logic which is increasingly being used in domestic appliances and is in use in many industrial applications. Finally, learners are introduced to artificial neural networks, which are related to basic brain (synapse) functions, and 'learning' is demonstrated using simple neuron structures. Evaluation of fuzzy logic algorithms and artificial neural networks is achieved via simulation using proprietary software.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand the use of knowledge-based and rule-based systems

2 Be able to use fuzzy logic

3 Be able to use artificial neural networks.

Unit content

1 **Understand the use of knowledge-based and rule-based systems**

Knowledge and rule base: terminology (facts and rules, propositions or predicates, deep and surface knowledge – heuristics); semantic networks; forward chaining; antecedents and consequences; conflict resolution; backward chaining; applications and implementation (identification of examples where such systems would be used)

2 **Be able to use fuzzy logic**

Human analogy: human reasoning and expert knowledge

Fuzzy logic theory: conventional binary logic; crisp and fuzzy sets; fuzzy reasoning; fuzzy rules; membership functions; inference engines; de-fuzzification

Applications: identification and analysis of examples eg cameras, domestic appliances, industrial equipment and processes

Implementation: development of fuzzy rules; evaluation of performance via simulation

3 **Be able to use artificial neural networks**

Biological analogy: synapse, axons, dendrites

Network topologies and operating characteristics: Hopfield networks; multi-layer perceptron; back propagation; self organising networks; Kohonen networks; radial basis function networks; neuro-fuzzy and fuzzy-neural

Applications: identification and analysis of examples eg pattern classification, optical character recognition, image analysis, biometrics

Implementation: experimentation with neural network configurations; learning coefficients: RMS; error evaluation of performance via simulation

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Understand the use of knowledge-based and rule-based systems	1.1 explain knowledge-base and rule-base terminology 1.2 devise and interpret semantic networks 1.3 describe applications of knowledge-based and rule-based systems
LO2 Be able to use fuzzy logic	2.1 describe human reasoning and expert knowledge 2.2 use fuzzy logic theory to produce fuzzy rules, fuzzification and defuzzification 2.3 describe and evaluate applications of fuzzy logic 2.4 design and evaluate fuzzy logic systems using appropriate software
LO3 Be able to use artificial neural networks	3.1 explain the biological analogy of neural networks 3.2 explain network topologies and operating characteristics 3.3 describe and evaluate applications of neural networks 3.4 design and evaluate neural networks using appropriate software.

Guidance

Links

This is a stand-alone unit.

Essential requirements

The use of software packages is an essential part of the delivery of this unit. Proprietary software such as MATLAB/Simulink, or equivalent, with appropriate tool boxes for fuzzy logic and neural networks must be available to learners.

Employer engagement and vocational contexts

The delivery of this unit will benefit from centres establishing strong links with employers willing to contribute to the delivery of teaching, work-based placements and/or detailed case study materials.

Unit 41: Fluid Mechanics

Unit code: T/601/1445

Level: 4

Credit value: 15

Aim

The aim of this unit is to extend learners' knowledge of the principles of fluid mechanics and the techniques used to predict the behaviour of fluids in engineering applications.

Unit abstract

This unit will begin by looking at the forces exerted by a static fluid on immersed surfaces and the concept of centre of pressure. It also examines a range of hydraulic devices and systems that incorporate the transmission of hydraulic pressure. Learners will then examine viscosity in fluids, its measurement and the characteristics of Newtonian and non-Newtonian fluids.

The unit then examines fluid flow phenomena. These include the estimation of head loss in pipes, viscous drag around streamlined and bluff bodies and the concept of Reynolds' number. It also introduces learners to the techniques and applications of dimensional analysis. Finally, learners will examine the operational characteristics of hydraulic machines, in particular the operating principles of water turbines and pumps.

Learning outcomes

On successful completion of this unit a learner will:

1 Be able to determine the behavioural characteristics and parameters of static fluid systems

2 Understand the effects of viscosity in fluids

3 Be able to determine the behavioural characteristics and parameters of real fluid flow

4 Understand the operating principles of hydraulic machines.

Unit content

1 **Be able to determine the behavioural characteristics and parameters of static fluid systems**

Immersed surfaces: rectangular and circular surfaces eg retaining walls, tank sides, sluice gates, inspection covers, valve flanges

Centre of pressure: use of parallel axis theorem for immersed rectangular and circular immersed surfaces

Devices: hydraulic presses; hydraulic jacks; hydraulic accumulators; braking systems; determine outputs for given inputs

2 **Understand the effects of viscosity in fluids**

Viscosity: shear stress; shear rate; dynamic viscosity; kinematic viscosity

Viscosity measurement: operating principles and limitations of viscosity measuring devices eg falling sphere, capillary tube, rotational and orifice viscometers

Real fluids: Newtonian fluids; non-Newtonian fluids including pseudoplastic, Bingham plastic, Casson plastic and dilatent fluids

3 **Be able to determine the behavioural characteristics and parameters of real fluid flow**

Head losses: head loss in pipes by Darcy's formula; Moody diagram; head loss due to sudden enlargement and contraction of pipe diameter; head loss at entrance to a pipe; head loss in valves; flow between reservoirs due to gravity; hydraulic gradient; siphons; hammerblow in pipes

Reynolds' number: inertia and viscous resistance forces; laminar and turbulent flow; critical velocities

Viscous drag: dynamic pressure; form drag; skin friction drag; drag coefficient

Dimensional analysis: checking validity of equations such as those for pressure at depth; thrust on immersed surfaces and impact of a jet; forecasting the form of possible equations such as those for Darcy's formula and critical velocity in pipes

4 **Understand the operating principles of hydraulic machines**

Impact of a jet: power of a jet; normal thrust on a moving flat vane; thrust on a moving hemispherical cup; velocity diagrams to determine thrust on moving curved vanes; fluid friction losses; system efficiency

Operating principles of turbines: operating principles, applications and typical system efficiencies of common turbo-machines including the Pelton wheel, Francis turbine and Kaplan turbine

Operating principles of pumps: operating principles and applications of reciprocating and centrifugal pumps; head losses; pumping power; power transmitted; system efficiency

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Be able to determine the behavioural characteristics and parameters of static fluid systems	1.1 determine the hydrostatic pressure and thrust on immersed surfaces 1.2 determine the centre of pressure on immersed surfaces 1.3 determine the parameters of devices in which a fluid is used to transmit force
LO2 Understand the effects of viscosity in fluids	2.1 explain the characteristics of and parameters of viscosity in fluids 2.2 describe viscosity measurement techniques 2.3 describe the effects of shear force on Newtonian and non-Newtonian fluids
LO3 Be able to determine the behavioural characteristics and parameters of real fluid flow	3.1 determine head losses in pipeline flow 3.2 determine Reynolds' number for a flow system and assess its significance 3.3 determine viscous drag of bluff and streamlined bodies 3.4 apply dimensional analysis to fluid flow
LO4 Understand the operating principles of hydraulic machines	4.1 evaluate the impact of a jet of fluid on a moving vane 4.2 identify and explain the operating principles of water turbines and pumps.

Guidance

Links

This unit has links with *Unit 2: Engineering Science* and *Unit 61: Engineering Thermodynamics*.

Essential requirements

Learners will need access to laboratory facilities suitable for the investigation of viscosity, Reynolds' number for pipeline flow and the measurement of drag forces on bluff and streamlined bodies.

Employer engagement and vocational contexts

Liaison with industry can help centres provide access to relevant industrial facilities and related plant. Where possible work-based experience should be used to provide practical examples of fluid systems.

A visit to a utilities water treatment plant, pumping station or hydro-electric generating installation will enhance delivery of the unit.

Unit 42: Heat Transfer and Combustion

Unit code: K/601/1443

Level: 5

Credit value: 15

Aim

This unit will develop learners' understanding of heat transfer principles and empirical relationships enabling them to solve practical problems involving heat transfer, combustion and the specification of practical engineering equipment.

Unit abstract

This unit will build on learners' knowledge of the theory and associated formulae for heat transfer by conduction, convection and radiation. Learners will also analyse the materials used for lagging and their economic effects.

Learners will then study the applications of dimensional analysis, a more detailed treatment of heat transfer mechanisms and the determination of heat transfer coefficients. The unit goes on to look at the specification and performance of heat transfer equipment and learners are then introduced to the chemistry of the combustion process and analysis of the products of combustion.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand heat transfer rates for composite systems

2 Understand heat transfer mechanisms and coefficients

3 Be able to evaluate heat transfer equipment

4 Be able to analyse the combustion processes.

Unit content

1 **Understand heat transfer rates for composite systems**

Interfaces: conduction (Fourier's law, thermal conductivity, thermal resistance, temperature gradient, composite plane walls and thick cylinders); convection (description of forced and natural convection, convective heat transfer coefficient, film and overall coefficient)

Radiation: nature of radiation; Stefan-Boltzman law; black and grey body radiation; emissivity; absorptivity; correction for overall heat transfer coefficient

Lagging: material types; conductivity; energy costs; economic lagging

2 **Understand heat transfer mechanisms and coefficients**

Dimensional analysis: dimensionless groups; Reynolds, Nusselt, Prandtl, Stanton, Grashof numbers

Heat transfer mechanism: description of flow in tubes, ducts and across surfaces; boundary layer; laminar and turbulent; forced and natural convection; fluid properties; flow parameters; boiling and condensation

Determine heat transfer coefficients: Dittus-Boelter equation for forced convection in circular ducts and tubes, for various fluids, tube dimensions and flow parameters; use of charts and data for fluid properties

3 **Be able to evaluate heat transfer equipment**

Recuperators: concentric tube (parallel and counter flow, cross flow, shell and tube, plate, extended surface)

Heat transfer performance: steady state performance; overall heat transfer coefficient; log mean temperature difference (LMTD); effectiveness; pressure drop; fouling factors

Fluids: water; oil; air; refrigerants; steam

Applications: specification of suitable recuperator and fluids for given applications such as oil cooling and heat recovery; calculation of heat transfer rates given fluid and recuperator data

4 **Be able to analyse the combustion processes**

Combustion chemistry: composition of air and hydrocarbon fuels; combustion equations; stoichiometric and actual air:fuel ratios; mixture strength; excess air

Energy of combustion: calorific values; higher and lower; thermal and boiler efficiency; practical determination of calorific value of various solid, liquid and gaseous fuels

Products of combustion: instrumentation for flue gas and exhaust products; volumetric analysis; variation of proportions of products dependent on air:fuel ratio and combustion quality

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can**:
LO1 Understand heat transfer rates for composite systems	1.1 apply Fourier's law and the Newton rate equation to composite solids and fluid/solid interfaces 1.2 calculate heat transfer rates for combined modes including radiation 1.3 evaluate lagging for optimum performance
LO2 Understand heat transfer mechanisms and coefficients	2.1 apply dimensional analysis to energy and mass transfer relationships 2.2 evaluate heat transfer mechanisms 2.3 determine heat transfer coefficients using experimental and tabulated data
LO3 Be able to evaluate heat transfer equipment	3.1 evaluate various types and layout of recuperators 3.2 estimate heat transfer performance 3.3 specify recuperator type, size and fluids for given applications
LO4 Be able to analyse the combustion processes	4.1 derive combustion equations 4.2 determine calorific value 4.3 analyse products of combustion.

Guidance

Links

This unit can be linked with *Unit 41: Fluid Mechanics* or *Unit 61: Engineering Thermodynamics*.

Essential requirements

Centres will need to provide access to laboratory facilities suitable for the analysis of flow, heat exchange performance and products of combustion.

Employer engagement and vocational contexts

Liaison with industry can help centres provide access to relevant industrial facilities and related plant. Where possible work-based experience should be used to provide practical examples of heat transfer rates and mechanisms.

A visit to a power station or industrial site where waste heat recovery systems are in operation will be of value.

Unit 43: Plant and Process Principles

Unit code: H/601/1442

Level: 5

Credit value: 15

Aim

This unit will develop learners' understanding of some of the engineering principles that underpin the design and operation of plant engineering systems and equipment.

Unit abstract

It is envisaged that the content of this unit will be used as part of an integrated programme of plant engineering services and management, with the services aspect being applications orientated and developed through knowledge of thermofluid principles.

Learning outcome 1 will introduce learners to the concept of thermodynamic systems and their properties. This lays the foundation for the future study of heat engines. Learning outcome 2 seeks to provide learners with knowledge of common mechanical power transmission system elements. Learning outcome 3 will provide the learner with knowledge of static and dynamic fluid systems. This will lay the foundation for future study of fluid mechanics. In the final learning outcome, learners will investigate combustion processes, the associated chemistry and analysis of the products of combustion.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand thermodynamic systems as applied to plant engineering processes

2 Understand power transmission system elements in relation to plant engineering equipment

3 Understand static and dynamic fluid systems with reference to plant engineering

4 Understand combustion processes associated with plant engineering.

Unit content

1 **Understand thermodynamic systems as applied to plant engineering processes**

Thermodynamic systems: closed systems; open systems; application of 1st Law to derive system energy equations; enthalpy

Properties: system properties eg intensive, extensive, two-property rule

Polytropic processes: general equation $pv^n = c$; relationships between index ‘n’ and heat transfer during a process; constant pressure and reversible isothermal and adiabatic processes; expressions for work flow

Relationships: system constants for a perfect gas eg $R = c_p - c_v$ and $\gamma = c_p/c_v$

2 **Understand power transmission system elements in relation to plant engineering equipment**

Belt drives: flat and vee-section belts; limiting coefficient friction; limiting slack and tight side tensions; initial tension requirements; maximum power transmitted

Friction clutches: flat, single and multi-plate clutches; conical clutches; coefficient of friction; spring force requirements; maximum power transmitted by constant wear and constant pressure theories; validity of theories

Gear trains: simple, compound and epicyclic gear trains; determination of velocity ratios; torque, speed and power relationships; efficiency; fixing torques

3 **Understand static and dynamic fluid systems with reference to plant engineering**

Immersed surfaces: rectangular and circular surfaces, including retaining walls, tank sides, sluice gates, inspection covers, valve flanges; hydrostatic pressure and thrust on immersed surfaces

Centre of pressure: use of parallel axis theorem for immersed rectangular and circular surfaces

Viscosity: shear stress; shear rate; dynamic viscosity; kinematic viscosity

Pipeline flow: head losses eg Bernoulli’s equation and determination of head loss in pipes by D’Arcy’s formula; Moody diagram; head loss due to sudden enlargement and contraction of pipe diameter; head loss at entrance to a pipe; head loss in valves; Reynolds’ number; inertia and viscous resistance forces; laminar and turbulent flow; critical velocities

Impact of a jet: power of a jet; normal thrust on a moving flat vane; thrust on a moving hemispherical cup; velocity diagrams to determine thrust on moving curved vanes; fluid friction losses; system efficiency

4 **Understand combustion processes associated with plant engineering.**

Combustion chemistry: composition of air and simple hydrocarbon fuels; combustion equations; stoichiometric and actual air:fuel ratios; mixture strength; excess air

Energy of combustion: calorific values; higher and lower; thermal and boiler efficiency; practical determination of calorific value of various solid, liquid and gaseous fuels

Products of combustion: instrumentation for flue gas and exhaust products; volumetric analysis; variation of proportions of products dependent on air:fuel ratio and combustion quality

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Understand thermodynamic systems as applied to plant engineering processes	1.1 discuss thermodynamic systems and their properties 1.2 examine the application of the 1st law of thermodynamics to thermodynamic systems 1.3 evaluate polytropic processes 1.4 determine the relationships between system constants for a perfect gas
LO2 Understand power transmission system elements in relation to plant engineering equipment	2.1 determine the maximum power which can be transmitted by means of a belt and by a friction clutch 2.2 determine the torque and power transmitted through gear trains
LO3 Understand static and dynamic fluid systems with reference to plant engineering	3.1 determine the hydrostatic pressure and thrust on immersed surfaces 3.2 determine the centre of pressure on immersed surfaces 3.3 explain viscosity in fluids 3.4 determine fluid flow in a pipeline 3.5 assess the impact of a jet of fluid
LO4 Understand combustion processes associated with plant engineering	4.1 explain the combustion process using terminology associated with combustion chemistry 4.2 determine energy of combustion 4.3 explain how products of combustion are formed.

Guidance

Links

This unit can be linked with *Unit 1: Analytical Methods for Engineers* and *Unit 2: Engineering Science*. It can also support the delivery of *Unit 41: Fluid Mechanics* and *Unit 61: Engineering Thermodynamics*.

Essential requirements

Centres will need to provide access to laboratory facilities for the investigation of fluid flow and a hydraulics bench with attachments for the investigation of pipeline flow and the impact of a jet of fluid. Facilities will also need to be available for the investigation of combustion processes and the calorimetric properties of gases and fuels.

Employer engagement and vocational contexts

Liaison with plant engineering and process companies would be useful in giving learners the opportunity to witness the operation of plant engineering systems and equipment at first hand.

Unit 44: Plant Maintenance and Decommissioning

Unit code: H/601/1439

Level: 4

Credit value: 15

Aim

This unit will develop learners' understanding of the types and need for maintenance of engineering plant and the skills needed to prepare maintenance procedures and evaluate decommissioning procedures.

Unit abstract

This unit will examine a number of recognised engineering maintenance procedures which can be adapted to any engineering plant equipment environment.

Based on an understanding of maintenance procedures and policies, learners will be expected to identify good practice. They should then be able to devise a maintenance procedure and a management strategy for engineering plant and equipment in the workplace.

Within the chemical, oil, gas, nuclear and allied industries the need to undertake decommissioning of plant is increasingly important and the final learning outcome of this unit is designed to evaluate the decommissioning procedure.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand the need for and types of maintenance associated with engineering plant and equipment

2 Be able to prepare and evaluate maintenance procedures and related documentation for engineering plant

3 Be able to identify and evaluate decommissioning procedures for engineering plant.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017

Unit content

1 **Understand the need for and types of maintenance associated with engineering plant and equipment**

Need for maintenance: efficiency; extended operating life; uptime, downtime, mean time between failure; legal requirements

Type of maintenance: planned; preventative; predictive; scheduled; unscheduled; corrective; emergency; requirements for monitoring eg use of training manuals, schedules

Health and safety: national regulations and standards; safety and environmental requirements in relation to maintenance operations

2 **Be able to prepare and evaluate maintenance procedures and related documentation for engineering plant**

Maintenance procedures: type; company and industry standards and practices; activities

Management strategies: identification and management of resource requirements eg personnel, supporting equipment, facilities, materials; costs and maintenance documentation eg communicating information, plans and schedules; evaluation criteria

3 **Be able to identify and evaluate decommissioning procedures for engineering plant**

Decommissioning: equipment identification; complete or part decommission; disposal; decommissioning requirements eg health and safety, environmental; plans and schedules; resources; evaluation criteria

Information and recording: resource planning; programming and sequencing; regulations compliance; recording maintenance processes; safety; sustainability and environmental issues; evaluation criteria

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Understand the need for and types of maintenance associated with engineering plant and equipment	1.1 explain need for maintenance of plant in an engineering environment 1.2 describe the types of maintenance associated with engineering plant and equipment 1.3 determine and explain the requirements for monitoring of maintenance procedures 1.4 specify the health and safety requirements in relation to maintenance
LO2 Be able to prepare and evaluate maintenance procedures and related documentation for engineering plant	2.1 justify and prepare maintenance procedures for a given plant engineering situation 2.2 determine resource requirements, identify costs and prepare maintenance documentation 2.3 evaluate maintenance procedures against relevant criteria
LO3 Be able to identify and evaluate decommissioning procedures for engineering plant	3.1 identify the appropriate decommissioning requirements and procedures 3.2 ensure compliance of all information and recording processes 3.3 determine appropriate criteria for evaluating both procedures 3.4 evaluate decommissioning procedures against relevant criteria.

Guidance

Links

The unit can stand alone but may be linked with other units including *Unit 7: Business Management Techniques for Engineers* and *Unit 45: Plant Operations and Performance*.

The unit can also be linked to the SEMTA National Occupational Standards in Engineering Management, particularly Unit 4.24: Propose Decommissioning of Engineering Equipment, Processes or Facilities.

Essential requirements

Centres delivering this unit will need access to industrial-standard software packages incorporating systems for maintenance management.

Employer engagement and vocational contexts

Liaison with plant engineering and process companies would be useful to give learners the opportunity to witness actual maintenance activities first hand.

Unit 45: Plant Operations and Performance

Unit code: D/601/1438

Level: 5

Credit value: 15

Aim

This unit will develop learners' understanding of the installation, commissioning, performance and efficient functioning of engineering plant and equipment.

Unit abstract

This unit will examine the performance and efficient functioning of engineering plant and equipment. It covers the installation and commissioning of a component or section of engineering plant, the monitoring of plant performance and the evaluation of performance capability. This in turn should enable learners to recognise differences between the design and operational characteristics of engineering plant and equipment. On working through the unit the learner should be able to relate performance characteristics of particular engineering plant to basic thermodynamic and mechanical engineering principles covered in other units.

Through case studies learners will examine the performance of individual components and the system in a suite of air compressors providing compressed air to a factory complex; a packaged gas turbine unit generating power as part of a closed cycle gas turbine (CCGT) plant; or an air conditioning plant used in an industrial or commercial complex. Learners may use tables, nomograms, file data etc, to establish component and system characteristics.

Learning outcome 1 introduces learners to planning and installation procedures and to heath and safety issues. Learning outcome 2 covers commissioning procedures, the acceptance and hand-over of plant. Learning outcome 3 will familiarise the learner with monitoring and recording procedures whilst the final learning outcome is concerned with the evaluation of performance data to ascertain plant efficiency and economy of operation.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand how to plan the installation of engineering plant and equipment to meet identified specifications

2 Understand how to undertake commissioning procedures on engineering plant and equipment to achieve operational objectives

3 Be able to monitor the operational performance of engineering plant and equipment

4 Understand the performance capability of engineering plant and equipment.

Unit content

1 **Understand how to plan the installation of engineering plant and equipment to meet identified specifications**

Specifications: planning requirements; resources required; health and safety aspects

Planning: new/existing plant; regulations; systems and services; procedures; schedules

Resources: personnel; equipment; materials; costs; services

Health and safety: national regulations and standards; company procedures

2 **Understand how to undertake commissioning procedures on engineering plant and equipment to achieve operational objectives**

Planning: objectives; regulations; schedules; procedures; safety; hand-over

Operation: acceptance tests; component tests; start-up; shut-down; full load; part load; malfunction; failure; operator errors; objectives

Recording: performance characteristics; data analysis; evaluation; feedback; source data

3 **Be able to monitor the operational performance of engineering plant and equipment**

Planning: planning; manuals; regulations; safety

Monitoring of operation: normal/abnormal running; full/part/over load; operating costs; equipment performance characteristics; reliability

Recording: parameters, data sources; qualitative/quantitative data analysis; component and system characteristics; predicted efficiencies; performance data

4 **Understand the performance capability of engineering plant and equipment**

Planning: planning; manuals; regulations; safety

Operation: steady-state conditions; system and component characteristics performance; efficient and economical performance; quality control; reliability

Recording: relevant parameters, data sources; actual and rated performance characteristics; system and component efficiencies; system and plant performance optimisation

Proposals: remedial action; impact on system

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Understand how to plan the installation of engineering plant and equipment to meet identified specifications	1.1 assess specifications and schedules for the installation of engineering plant and equipment 1.2 justify the overall cost of installing engineering plant and equipment 1.3 describe necessary health and safety checks for the installation of engineering plant and equipment
LO2 Understand how to undertake commissioning procedures on engineering plant and equipment to achieve operational objectives	2.1 determine operational objectives in commissioning engineering plant and equipment 2.2 explain the use of procedures and schedules for commissioning 2.3 describe component and acceptance tests involved in commissioning
LO3 Be able to monitor the operational performance of engineering plant and equipment	3.1 plan the procedures used to monitor engineering plant and equipment parameters 3.2 report on the relevance and reliability of parameters and data sources 3.3 report on performance data in relation to operational objectives
LO4 Understand the performance capability of engineering plant and equipment	4.1 justify when the operational performance of a system is in steady state 4.2 compare evaluated and rated performance characteristics for relevant engineering plant and equipment 4.3 propose remedial action to improve performance.

Guidance

Links

This unit links with *Unit 43: Plant and Process Principles.*

The unit can be linked to the SEMTA Level 4 National Occupational Standards in Engineering Management, particularly 4.21: Commission Engineering Products, Processes or Facilities.

Essential requirements

Centres will need to provide access to a range of relevant engineering plant, either directly or through local industrial organisations.

Employer engagement and vocational contexts

Centres should try to work closely with industrial organisations, especially where there may be limited resources. Visits to one or two relevant industrial or commercial organisations to review plant operations and performance will be of value to enhance and support learning.

Unit 46: Plant and Process Control

Unit code: L/601/1435

Level: 5

Credit value: 15

Aim

This unit aims to develop learners' understanding of time and frequency domain analysis of plant and process control systems and the use of controller designs to achieve specified system performance.

Unit abstract

This unit will develop learners' understanding of the limitations of standard controllers and the use of more complex control schemes.

The first learning outcome will enable learners to recognise the characteristics of first and second order control systems and to analyse their response to step and ramp inputs. Learners are introduced to closed loop transfer functions and proportional/integral/derivative control actions. They will then apply this knowledge to analyse the requirements and design a control system in the time domain.

Learners are introduced to the response to a sinusoidal input and the conditions for system stability. They will analyse the requirements and design a control system in the frequency domain. Finally, learners will investigate the need for, and the use of, multi-loop and complex control systems.

Learning outcomes

On successful completion of this unit a learner will:

1 Be able to predict the dynamic and steady state response of an engineering system

2 Be able to design a control system in the time domain to a specified performance requirement

3 Be able to design a control system in the frequency domain to meet a specified performance requirement

4 Understand the need for and use of multi-loop and complex control systems.

Unit content

1 **Be able to predict the dynamic and steady state response of an engineering system**

Representation: first and second order differential equation models of simple engineering systems; standard form of equation; determine transfer functions from differential equation models

Analysis: output response to step and ramp inputs; dominant response

Specification and identification: gain; time constant; damping ratio; overshoot; natural and damped frequencies; rise time; settling time

2 **Be able to design a control system in the time domain to a specified performance requirement**

Closed loop: block-diagram manipulation; closed-loop transfer function; dynamic response; steady state response

Specification: dominant response; rise time; settling time; steady state error; overshoot

Controllers: review of the effects of P, I and D actions, parameter adjustment and tuning; approximate digital algorithm representation; sampling rate

Design: dynamic and steady state requirements; controller configuration; choice of actions; controller coefficient values; tuning; entry point of disturbances

3 **Be able to design a control system in the frequency domain to meet a specified performance requirement**

Frequency response: response to sinusoidal input; phase; gain; Bode frequency response plot; first order and second order systems; cascaded higher order; transport lag

Stability: gain and phase margins for simple systems; effect of P, I and D actions

Specification: steady-state error; gain and phase margins; bandwidth; link to time domain requirements

Design: dynamic and steady-state requirements; controller configuration; choice of actions; controller coefficient values; tuning

4 **Understand the need for and use of multi-loop and complex control systems**

Single-loop, three-term control: limitations; controllability; entry point of disturbances; changes in system dynamics; non-linear gain; multi-loop systems; interactions; de-tuning; averaging control

Multi-loop: ratio; cascade; feed forward; split range; hi-lo select; SCADA systems

Advanced control: gain scheduling; self-tuning; fuzzy; predictive; Smith predictor

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Be able to predict the dynamic and steady state response of an engineering system	1.1 determine transfer functions from differential equation models 1.2 manipulate first and second order transfer functions into standard form and extract standard coefficients 1.3 determine output response to step and ramp inputs
LO2 Be able to design a control system in the time domain to a specified performance requirement	2.1 manipulate transfer functions and determine closed-loop transfer function 2.2 determine closed-loop dynamic and steady state parameters 2.3 design a controller to meet given performance criteria 2.4 assess the effect of controller settings on steady state and dynamic response
LO3 Be able to design a control system in the frequency domain to meet a specified performance requirement	3.1 examine response of systems to sinusoidal inputs and plot Bode frequency response plots 3.2 determine frequency response of higher order systems 3.3 predict stability and time domain performance of a closed loop system from open loop frequency response 3.4 design a controller to meet given performance criteria 3.5 assess the effect of controller settings on frequency and time response
LO4 Understand the need for and use of multi-loop and complex control systems	4.1 identify the limitations of PID control in ensuring effective control in some situations 4.2 investigate alternative control strategies 4.3 investigate and review some advanced control strategies.

Guidance

Links

This unit links to *Unit 1: Analytical Methods for Engineers* and *Unit 2: Engineering Science* prior to this unit.

Essential requirements

A range of laboratory rigs, test equipment and appropriate software packages will need to be available to support practical investigations.

Employer engagement and vocational contexts

Centres should try to work closely with industrial organisations in order to bring realism and relevance to the unit. Visits to one or two relevant industrial or commercial organisations to review plant control systems will be of value to enhance and support learning.

Unit 47: Engineering Plant Technology

Unit code: F/601/1433

Level: 5

Credit value: 15

Aim

This unit will develop learners' understanding of the operation and testing of engineering plant and the application of the related underpinning principles of operation.

Unit abstract

It is desirable that technicians and engineers who are concerned with the design, installation and operation of power generation plant and plant services have a broad-based practical and theoretical knowledge of the sector. Safe operating and testing procedures form an essential part of this knowledge base for those involved in the day-to-day running and servicing of plant equipment.

The aim of this unit is to investigate the relationships between theory and practice for the various items of plant. The first learning outcome aims to provide knowledge of safe operating and testing procedures. The second and third learning outcomes seek to give an understanding of the energy changes and energy flow, which occur in power generation and service plant. The final learning outcome is concerned with prime movers in the form of diesel engines, steam turbines and gas turbines. Its aim is to provide knowledge of the different configurations and an assessment of their performance.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand procedures for safe and effective operation and testing of plant

2 Be able to apply the steady flow energy equation (SFEE) to plant and equipment

3 Be able to apply the principles of heat transfer to plant processes

4 Be able to analyse and report on the performance of power supply equipment.

Unit content

1 **Understand procedures for safe and effective operation and testing of plant**

Safe operating procedures: pre start-up checks; start-up; running and shutdown procedures; permit to work; emergency procedures

Testing procedures: performance monitoring eg collation of data and results, flow variables such as temperature, pressure, volume flow, abnormal conditions, quality control, corrective action; performance testing eg comparison of measured results with accepted norms for criteria such as power, efficiency, heat loss, power factor, slip

2 **Be able to apply the steady flow energy equation (SFEE) to plant and equipment**

SFEE: consideration and applications of continuity of mass; first law of thermodynamics; principle of conservation of energy; work flow; heat transfer; kinetic energy; potential energy; pressure-flow energy; internal energy; enthalpy

Application of SFEE to plant: assumptions made in specific applications; energy transfer and efficiency calculations for specific items of plant eg economisers, boilers, super-heaters, turbines, pumps, condensers, throttles, compressors; boiler efficiency

3 **Be able to apply the principles of heat transfer to plant processes**

Composite walls: overall heat transfer coefficient (U) for standard structures eg furnaces and refrigerators; k value applied to composite walls; interface temperatures; boundary layer effects on single layer walls; comparison of refrigerator casing with furnace walls

Heat exchangers: direct injection of water into steam; shell and tube designs; thin cylinder heat transfer; parallel and counter flow; casing losses; coefficient of performance of condensers

Pipes: comparison of heat losses through lagged and unlagged pipes; k values applied to thin and thick cylinders; optimum lagging thickness

4 **Be able to analyse and report on the performance of power supply equipment**

Diesel engines: specific applications of diesel engines and analysis of relevant performance parameters eg compression ratio, fuel cut-off ratio, air standard efficiency for low speed and medium/high speed diesel engines, engine trials, 2 and 4 stroke effect on output, indicated and brake mean effective pressure, indicated and brake power, indicated and brake thermal efficiency, mechanical efficiency, relative efficiency, specific fuel consumption

Steam turbines: measurement of power output; effect of temperature change across turbine; impulse and reaction principles; pass out; back pressure and condensing turbines; avoidance of wet steam; limitations on efficiency

Gas turbines: single and double shaft; regeneration and reheat; efficiency with and without regeneration; economics of gas turbine

Alternative energy sources: wind turbines, wave energy, waste recycling, geothermal

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Understand procedures for safe and effective operation and testing of plant	1.1 analyse and review safe operating and testing procedures 1.2 interpret data and results to produce written reports 1.3 compare test results with accepted norms
LO2 Be able to apply the steady flow energy equation (SFEE) to plant and equipment	2.1 derive, from first principles, the steady flow energy equation 2.2 specify assumptions when applying SFEE to plant items 2.3 generate and apply specific equations based on stated assumption to specific plant items
LO3 Be able to apply the principles of heat transfer to plant processes	3.1 apply formulae involving U and k values to composite walls 3.2 realise the effect of boundary layers 3.3 apply heat transfer formulae to heat exchangers 3.4 compare heat losses through lagged and unlagged pipes
LO4 Be able to analyse and report on the performance of power supply equipment	4.1 analyse and report on the performance of a diesel engine 4.2 analyse and report on the performance of a steam turbine 4.3 analyse and report on the performance of a gas turbine.

Guidance

Links

This unit can be linked with *Unit 2: Engineering Science* and *Unit 41: Fluid Mechanics*.

Essential requirements

Centres need to provide access to suitable laboratory facilities for the investigation of energy transfer.

Employer engagement and vocational contexts

Liaison with employers would prove of benefit to centres, especially if they are able to offer access to suitable industrial plant and equipment.

Unit 48: Analytical and Chemical Composition Measurement

Unit code: A/601/1432

Level: 4

Credit value: 15

Aim

This unit will develop learners' understanding of the techniques used in the detection of variables in industrial processes.

Unit abstract

The unit seeks to develop an understanding of modern measurement principles and recognition of how these concepts are applied in the design of commercial instruments for the measurement of both analytical and chemical composition variables.

Learning outcome 1 develops the principles, techniques and equipment used in process sampling. In learning outcome 2, learners will become familiar with the analytical measuring instruments used with a range of process variables. The final learning outcome considers the measurement of chemical composition and introduces the learner to a range of instruments, their principles of operation, design, selection and calibration.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand the principles of process sampling

2 Understand the principles, design and operation of analytical measurement instruments

3 Understand the principles, design, operation and developments of chemical composition measurement instruments.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017 © Pearson Education Limited 2017

Unit content

1 **Understand the principles of process sampling**

Representative sample: process parameter; physical/chemical properties; probe location; sample conditioning; average sample; lags; intrusive/non-intrusive measurement

System components: sensor; signal conditioning; transmission; display; probe; filters; coolers; dryers; pumps; traps

Design and maintenance: environmental factors; temperature; pressure; humidity; corrosion; mechanical shock; leakage; blockage and contamination; frequency of site checks; inspection; routine maintenance and calibration; safety considerations

Design: nature of measurand; choice of materials; layout; dimensional limits

2 **Understand the principles, design and operation of analytical measurement instruments**

Principle of operation: gas analysers; dumbell; zirconium cell; electro-chemical cell; cooled mirrors; wet and dry bulb

Measurement: density; differential pressure; magnetic wind; frequency of vibration; absorption considerations eg radiation, moisture, fibres; hydroscopicity; capacitance; electrical conductivity; infra-red; viscosity; Newtonian/non-Newtonian fluids; capillary; torque

Design features: shaped vane construction; fixed aperture; accuracy; response; cost; environmental factors; scales

Selection: transducer; measurand characteristics; manufacturers' data sheets

Evaluation: evaluation of an analytical measurement system eg calibration; standards; traceability; standard samples; storage life; standard procedures; safety

3 **Understand the principles, design, operation and developments of chemical composition measurement instruments**

Principle of operation: pH; acid; alkaline; hydrogen ion concentration; buffer solutions; ion and design specific electrode; glass electrode; calomel reference electrode; isopotential; point; measuring circuits

Measurement: redox oxidation, redox potential; conductivity eg atoms, molecules, ions, electrolyte, ionic concentration, cell constant; chromatography eg chemical extraction, partition coefficient, elution, peak resolution, carrier gas

Design features: evaluation of design features such as detectors eg thermal conductivity detectors, flame ionisation detectors, electron capture detectors; data presentation; construction accuracy; response; cost; environmental factors; sensitivity; accuracy of measurement

Selection: transducer; measurand characteristics; use of manufacturers' technical data sheets to select transducer for given application

Evaluation: evaluation of a chemical composition measurement system eg calibration, standards, traceability, standard samples, storage life, standard procedures, safety

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Understand the principles of process sampling	1.1 explain the importance of sampling and explain the need for provision of a representative sample 1.2 describe essential sample components for continuous measurements in typical process systems 1.3 explain general design, maintenance and safety considerations for typical sampling systems 1.4 design a sampling system
LO2 Understand the principles, design and operation of analytical measurement instruments	2.1 explain the principle of operation of analytical measurement methods 2.2 describe the design features of a range of analytical measurement instruments 2.3 select the transducer capable of making a specified measurement, using manufacturers' technical data sheets 2.4 evaluate a measurement system which is relevant to the learner's place of work
LO3 Understand the principles, design, operation and developments of chemical composition measurement instruments	3.1 explain the principle of operation of chemical composition measurement methods 3.2 evaluate design features of thermal conductivity detectors, flame ionisation detectors and electron capture detectors 3.3 select the transducer capable of making a specified measurement, using manufacturers' technical data sheets 3.4 evaluate a measurement system which is relevant to the learner's place of work.

Guidance

Links

This unit is designed to be stand-alone, but it has links with *Unit 55: Instrumentation and Control Principles.*

Essential requirements

Centres delivering this unit will need to provide access to industrial standard process instrumentation systems. A variety of system components will also need be available for demonstration purposes and hands-on familiarisation.

Employer engagement and vocational contexts

Visits to industrial installations will be of value to supplement learning activities and provide learners with a perspective on scale and application of instrumentation technologies.

Unit 49: Computer Control of Plant

Unit code:	M/601/1427
Level:	4
Credit value:	15

Aim

This unit aims to develop learners' ability to design and use computer systems to monitor and control engineering and industrial plant.

Unit abstract

The unit introduces learners to the required programming techniques and provides knowledge of the electronic and communication systems used in modern process and manufacturing plant. Learners will develop the skills needed to modify or up-date existing distributed-intelligence systems. Extensive use will be made of computer-simulated packages and rigs to provide the learner with hands-on experience.

In learning outcome 1, learners will investigate computer control strategies for complex control systems and select appropriate strategies to meet given specifications. In learning outcome 2, learners analyse the characteristics of remote smart sensors/ devices together with their interfacing/configuration. Learning outcome 3 is concerned with plant monitoring techniques and learning outcome 4, learners will investigate and analyse a modern computer controlled system.

Learning outcomes

On successful completion of this unit a learner will:

1 Be able to select computer control strategies for a complex control system

2 Be able to select remote smart sensors/devices to meet given specification

3 Be able to select and develop programs and use machine interfaces to monitor plant operation

4 Understand the different types of data communication systems used in control and instrumentation.

Unit content

1 **Be able to select computer control strategies for a complex control system**

Select: to meet given specification; alternative computer control strategies; justification of choice eg easy to maintain, flexible enough to accommodate change as production needs change

Control strategy: direct-intelligent devices to share information; supervisory control and data acquisition (SCADA); distributed control; manufacturing automation protocol (MAP); device configuration to given specification; programming; alarm systems; topology and maintenance considerations

2 **Be able to select remote smart sensors/devices to meet given specification**

Data conversion: analogue to digital conversion (ADC) and digital to analogue conversion (DAC)

Sensors: operation, characteristics and limitations of the various sensors and devices; process measurement; smart sensors; custom designed chip sensors; embedded systems; applications that include a wide range of external devices/sensors; interface/configure two different sensors/devices to the computer system

3 **Be able to select and develop programs and use machine interfaces to monitor plant operation**

Programming: use and development of programs for host computer/PLCs, including hierarchy of information accesses (security); solution of real control problems eg could be simulations on controlled rigs

Standard techniques: collection of data

Condition monitoring: traditional/expert systems

Commercially available displays and devices: configure display devices to a given format for operators and maintenance staff; appraisal of plant display and process mimic devices eg for applications, ergonomics; design operator interface information; acquisition of continuous data display for real time production planning and control

4 **Understand the different types of data communication systems used in control and instrumentation**

Communication systems A: International Standards Organisation (ISO) 7 layer model; frequency division multiplexing (FDM); time division multiplexing (TDM); multi-drop systems; bit and byte synchronisation; phase encoding; RS 232; local area networks (LANs); optical and wireless communications

Communication systems B: 4-20mA voltage/current transmitters; RS 232 transmitter; IEEE 488 bus, HART (Rosemount) system; fieldbus requirements/details in both manufacturing and process industries

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Be able to select computer control strategies for a complex control system	1.1 identify and review alternative computer control strategies 1.2 select and implement the appropriate strategy to meet a specification 1.3 demonstrate that the chosen strategy is easy to maintain and flexible enough to accommodate change as production needs change
LO2 Be able to select remote smart sensors/devices to meet given specification	2.1 select appropriate sensors/devices to meet a specification 2.2 describe the operation, characteristics and limitations of the various sensors and devices 2.3 interface/configure two different sensors/devices to the computer system
LO3 Be able to select and develop programs and use machine interfaces to monitor plant operation	3.1 select/develop programs to solve real control problems, these could be simulations on controlled rigs 3.2 appraise ergonomics of commercial plant displays and process mimic devices 3.3 configure display devices to a given format for operators and maintenance staff 3.4 acquire continuous data display for real time production planning and control
LO4 Understand the different types of data communication systems used in control and instrumentation	4.1 explain the different types of communication used in control and instrumentation systems 4.2 explain the layering and structure of the ISO 7 layer model 4.3 describe the use of LANs in a factory/plant environment 4.4 identify the requirements of fieldbus and explain its protocols 4.5 describe the use of fieldbus in control network systems.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017

Guidance

Links

This unit may be linked to *Unit 22: Programmable Logic Controllers* and *Unit 46: Plant and Process Control*.

Essential requirements

Centres will need to provide access to computer/PLC-controlled rigs, set up to control a process, assembly line or product production.

Employer engagement and vocational contexts

Centres should liaise with local industry so that learners have access to modern industrial plant.

Unit 50: Condition Monitoring and Fault Diagnosis

Unit code:	R/601/1422
Level:	5
Credit value:	15

Aim

This unit aims to provide learners with an understanding of condition monitoring techniques and will enable them to systematically locate and diagnose faults.

Unit abstract

Industrial process and power generation plant and many other engineering systems need to operate reliably for comparatively long periods of time. Condition monitoring can be of great assistance in ensuring this and is an essential element of preventative maintenance. It can signal the need for intervention to avoid expensive failures and system outages. Over a period of time, it can also provide data to assist in the planning and adjustment of a preventative maintenance programme.

This unit first examines the general concepts of condition monitoring, including the causes of failure, monitoring methods and the analysis of data. Learners will then look at a range of condition monitoring techniques such as those used to detect leaks, corrosion and cracking in engineering systems and plant.

Learners will study and apply a range of checks, tests and other techniques in order to diagnose, locate and identify system faults. Finally, learners will investigate the more common causes and effects of failure and, using a range of techniques, will analyse the cause and effect of such failure/s on system performance.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand the concepts of condition monitoring

2 Understand the nature and use of condition monitoring techniques

3 Be able to locate faults in engineering systems

4 Be able to analyse the cause and effect of faults in engineering systems.

Unit content

1 **Understand the concepts of condition monitoring**

Failure and breakdown: degradation due to corrosion, cracking, fouling, wear, ageing, mal-operation, environmental effects, operational and maintenance considerations; statistical analysis of failure rates on plant and equipment

Monitoring: arrangements and measured parameters (‘online’ and ‘offline’ monitoring, fixed and portable monitoring equipment, continuous and semi-continuous data recording, stress analysis)

Data analysis: data analysis eg computerised systems, data acquisition techniques, use of generic computer software (such as spreadsheets, databases), fault analysis/diagnosis, plant down time analysis, data storage techniques, high-speed data capture, trend analysis, expert systems, condition monitoring integrated within ‘normal’ plant and machinery control and data acquisition systems

2 **Understand the nature and use of condition monitoring techniques**

Vibration: broad band defect detection; frequency spectrum analysis; shock pulse method; high-frequency analysis techniques

Leak detection: acoustic emission and surveillance; moisture sensitive tapes; radiotracer/radio-chemical methods

Corrosion detection: chromatography; eddy currents; electrical resistance; tangential impedance meter; IR spectroscopy; potential monitoring; thermograph; lasers

Crack detection: ultrasonic methods; optical fibres; lasers; strain gauges; electrical potential method; eddy currents; acoustic emission; thermography

Temperature: thermography; thermometry; thermistors; thermocouple devices; RTDs; optical pyrometers; IR pyrometers; lasers

3 **Be able to locate faults in engineering systems**

Information and documentation: plant personnel; alarm systems; component data sheets; block diagrams; flow charts; dependency charts; trouble shooting charts; wiring and schematic diagrams; circuit diagrams; system diagrams; operation and maintenance manuals; computerised records and data; use of internet

Inspection and test: characteristics of system; online/offline testing; test equipment; electrical/electronic/software based; self-diagnostic techniques; expert systems; safety requirements; safety and damage limitation

Fault location techniques: appropriate sources of information identified and selected; analysis of evidence; systematic and logical approach to fault finding; cause of fault evaluated and verified

4 **Be able to analyse the cause and effect of faults in engineering systems**

Causes of failure: mal-operation; environmental; lack of maintenance; operation outside design specifications; infrequent use, too frequent use; the ‘bath tub’ curve; reliability; common mode failure

Effects of failure: safety, economic, downtime, loss of production etc; failure states of components within a system

Analytical techniques: failure mode and effect analysis; fault tree analysis; cause and effect analysis

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Understand the concepts of condition monitoring	1.1 describe the causes of failure and breakdown in plant and equipment and explain the use of statistical data for analysing such failure/breakdown 1.2 describe plant and machinery monitoring arrangements and explain the relative merits of each arrangement 1.3 provide a computer data analysis printout of machine operating parameters 1.4 explain how condition monitoring may be integrated within normal plant and machinery, control and data acquisition systems
LO2 Understand the nature and use of condition monitoring techniques	2.1 explain the nature of the condition monitoring techniques used to monitor temperature and vibration and to detect leakage, corrosion and cracks 2.2 analyse an overall system for plant and machinery condition monitoring and report findings
LO3 Be able to locate faults in engineering systems	3.1 investigate and identify sources of information and documentation used as an aid to fault finding and fault location and report on their usefulness 3.2 select appropriate inspection and test equipment for fault location 3.3 carry out appropriate fault finding procedures to locate and verify faults in systems
LO4 Be able to analyse the cause and effect of faults in engineering systems	4.1 investigate and report on the causes of failure and identify the failure states of components within a given system 4.2 carry out a failure mode and effect analysis 4.3 carry out a fault tree analysis 4.4 prepare a cause and effect diagram.

Guidance

Links

This unit may be linked with other plant/process and engineering maintenance units, particularly *Unit 45: Plant Operation and Performance*.

Successful completion of this unit will enable learners to meet, in part, the Engineering Council Standards for Professional Engineering Competence (UK-SPEC), detailed below:

- Engineering Technician (Eng Tech) B1 standard 'identify problems and apply diagnostic methods to identify causes and achieve satisfactory solutions'
- Incorporated Engineer (IEng) standard A2 sub-paragraph 4 'Apply knowledge and experience to investigate and solve problems arising during engineering tasks and implement corrective action'.

Essential requirements

Centres delivering this unit must be equipped with, or have access to, industrial-standard condition monitoring equipment, instrumentation and facilities/equipment suitable for testing/fault finding. A range of system components for demonstration purposes and hands-on familiarisation will also need to be available.

Employer engagement and vocational contexts

Liaison with employers would prove of benefit to centres, especially if they are able to offer help with the provision of suitable industrial condition monitoring and fault-finding facilities and equipment.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering –
Issue 3 – November 2017 © Pearson Education Limited 2017

Unit 51: Emergency Shutdown and Safety Systems

Unit code: J/601/1420

Level: 4

Credit value: 15

Aim

This unit will provide learners with an understanding of safety shutdown systems as employed in modern industry.

Unit abstract

This unit will give learners an overview of the principles, technology, instrumentation and operational and maintenance requirements applied in safety shutdown systems. The unit can form the basis of further study at a more advanced level in this specialist area of instrumentation and control.

Learning outcome 1 will provide learners with knowledge and experience of the principles of safety shutdown. This includes safety shutdown philosophy and the aims and objectives of shutdown systems. Learning outcome 2 introduces the applied technology and techniques employed in safety shutdown systems. Learners will then evaluate the use of instrumentation in safety shutdown systems before investigating the operational and maintenance requirements.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand the principles of safety shutdown systems

2 Understand the applied technology and techniques used in safety shutdown systems

3 Understand the use of instrumentation in safety system applications

4 Understand the operational and maintenance requirements for safety shutdown systems.

Unit content

1 **Understand the principles of safety shutdown systems**

Principles: aims and objectives of shutdown systems eg protection of personnel, plant, equipment, safe operation, protection of the environment; hierarchy of protection eg ultimate protection through containment, pressure relief devices, bursting discs; automatic shutdown; manual shutdown; control systems to regulate processes and provide localised plant trips; alarm systems to provide audible and visual warning

Safety shutdown: analysis of hazard potential; hazard and operability (HAZOP); hazard analysis (HAZAN); failure mode and effect analysis (FMEA); failure to least hazardous condition; simplicity of system; evaluation of a conceptual proposal for an overall safety shutdown system

2 **Understand the applied technology and techniques used in safety shutdown systems**

Applied technology: logic arrangements; electrical; electronic (including software based); mechanical; pneumatic; hydraulic; input/output devices

Shutdown techniques: emergency 'back up' and support systems; local and remote shutdown arrangements; levels of shutdown dependent upon severity of hazard detected; module shutdown; plant/process shutdown; total installation shutdown; bypass arrangements; dispensation and exclusions from shutdown

Design criteria: independence of operation from other instrumentation and control systems; protection against external influences eg electromagnetic interference (EMI); logical structuring of alarm and shutdown sequences; interface arrangements with other systems eg fire and gas detection/protection systems and process/manufacturing control systems; override and resetting arrangements; reliability and availability of system; protection against common mode failure (CMF); segregation; diversity; redundancy; voting systems

3 **Understand the use of instrumentation in safety system applications**

Selection of instrumentation: manufactured to appropriate standards eg BS, CEN, ISO/IEC, ISA, ANSI; suitability for intended purpose and location

Safety applications for instrumentation: installation and maintenance requirements; input devices for detection of plant; process and manufacturing abnormalities; fire, gas, chemical, vapour, collision eg input sensors for level, pressure, temperature, speed, position; manual and automatic initiation; output shutdown devices eg actuators, valves, indicators, electrical/electronic trip switches

Hazardous area instrumentation: intelligent instrumentation for both input and output functions; hazardous area classification; zonal concept; principle of intrinsic safety and explosion proof equipment; standards eg BS, BASEEFA, CENELEC

4 **Understand the operational and maintenance requirements for safety shutdown systems**

Safety system operation: operation manual and operational procedures; personnel responsibilities; bypass arrangements; override operations; interlocks; monitoring of operational status of plant; equipment; manufacturing process; remote shutdown operations

Maintenance requirements: the need to meet statutory requirements; appropriate maintenance documentation and record keeping; inspection routines; online monitoring; manual and automatic testing; condition monitoring; event recording

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Understand the principles of safety shutdown systems	1.1 explain the principles of safety shutdown systems 1.2 evaluate a conceptual proposal for an overall process safety shutdown system
LO2 Understand the applied technology and techniques used in safety shutdown systems	2.1 identify the applied technology and techniques used in safety shutdown systems 2.2 explain the design criteria that are applied to safety shutdown systems
LO3 Understand the use of instrumentation in safety system applications	3.1 select suitable instrumentation for use in a safety shutdown application 3.2 identify specific requirements for safety instrumentation in a hazardous area environment 3.3 evaluate the use of instrumentation in a safety system application
LO4 Understand the operational and maintenance requirements for safety shutdown systems	4.1 determine the operational requirements for a safety shutdown system 4.2 determine the maintenance requirements for a safety shutdown system.

Guidance

Links

The unit has links with *Unit 6: Health and Safety and Risk Assessment in Engineering*, *Unit 24: Application of Pneumatics and Hydraulics* and *Unit 50: Condition Monitoring and Fault Diagnosis.*

Essential requirements

Centres delivering this unit must be equipped with simulated shutdown equipment to industrial standard or have access to industrial organisations offering such facilities.

Employer engagement and vocational contexts

Liaison with employers would be a benefit to centres, especially if they are able to offer access to suitable industrial plant and equipment.

Unit 52: Energy Management

Unit code: R/601/1419

Level: 5

Credit value: 15

Aim

The unit investigates energy management principles and techniques. The principal focus is to establish and develop an energy audit in the context of a plant engineering environment.

Unit abstract

This unit is concerned with energy conservation, including energy conservation awareness for both the organisation and personnel. Integral to the content is environmental management, which is now becoming ever increasingly important in energy conservation. Greater gains, both environmentally and economically, can be achieved by cutting down on waste and maximising the efficient use of energy.

Through case studies learners will investigate how environmental objectives and targets are achieved in different industrial or commercial organisations. Learners will understand how this is achieved through co-ordinating personnel, systems, strategy, resources and structures.

Learners will work on a project to ascertain the overall annual heat energy losses (or gains) of an operational building which houses plant engineering equipment and process plant. Architectural plans providing details of the building fabric and design may be helpful in calculating any heat energy gains or losses. The energy audit need not be confined to this type of project but to arrive at the outcomes the learner must demonstrate the ability to apply heat energy management concepts.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand environmental management policies

2 Know about energy sources, conservation and applications

3 Understand system and energy-saving requirements

4 Be able to carry out an energy management audit.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017 © Pearson Education Limited 2017

Unit content

1 **Understand environmental management policies**

Environmental management: environmental management systems and policies; regulatory requirements; ISO 14000/14001

Energy technologies: power generation; transportation

Resource management: waste; hazardous waste; water; air pollution

2 **Know about energy sources, conservation and applications**

Sources: fossil and non-fossil (biomass) fuels; alternative sources eg geothermal

Materials: thermal properties of materials; thermal conductors/insulators; K and U values

Applications: heat exchangers; recuperators; regenerators; waste products

3 **Understand system and energy-saving requirements**

Systems: system principles; combined heat and power (CHP) and combined cycle gas turbine (CCGT) plant

System analysis: energy analysis of the process eg Sankey diagram, influence of external environment, comparable systems

Cost savings: optimum (economic) lagging; break-even costs; no-cost/low-cost energy saving measures

4 **Be able to carry out an energy management audit**

Energy saving: range of quantifiable techniques; costing procedures

Audit: metering and measurement of temperature, flow, pressure; data collection and analysis

Monitoring: monitoring and targeting; setting targets; performance indices; indicators

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Understand environmental management policies	1.1 analyse the environmental management policies relevant to plant engineering 1.2 evaluate the types of energy technologies associated with plant engineering 1.3 assess the various aspects of resource management in the context of plant engineering
LO2 Know about energy sources, conservation and applications	2.1 define the various sources of fuel likely to be encountered in industry 2.2 describe the materials associated with energy conservation 2.3 identify industrial and commercial activities where energy conservation procedures can be adopted
LO3 Understand system and energy-saving requirements	3.1 assess systems which will provide an energy analysis 3.2 review a documented system analysis relating to the energy distribution 3.3 evaluate the appropriate cost-saving technique for the chosen situation
LO4 Be able to carry out an energy management audit	4.1 follow guidelines to determine the energy saving 4.2 specify the type, size and range of metering equipment as part of the audit process 4.3 set targets for performance parameters to be used whilst monitoring the processes.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017

Guidance

Links

This unit can be linked with *Unit 47: Plant Technology*.

Essential requirements

Centres delivering this unit will need to have access to industrial-standard software packages used for energy management procedures and audits.

Employer engagement and vocational contexts

Centres should try to work closely with industrial organisations in order to bring realism and relevance to the unit. Visits to one or two relevant industrial or commercial organisations which use energy management techniques will be of value to enhance and support learning.

Unit 54: Industrial Plant Services

Unit code: L/601/1418

Level: 5

Credit value: 15

Aim

This unit will develop learners' understanding of electrical supply systems, industrial compressors, steam services and refrigeration and heat pumps used in a range of engineering industrial plant.

Unit abstract

This unit will investigate and evaluate a range of services that are generally found in manufacturing and process plant. The approach is broad-based to reflect the fact that plant engineering encompasses more than one discipline. Its intention is to encourage learners to develop a holistic approach to the design, operation, installation and maintenance of plant services.

In learning outcome 1, learners are introduced to the operating principles of electrical power and lighting systems together with the relevant sections of the IEE regulations. Learning outcome 2 considers the principles of industrial compressed air systems and the associated health and safety considerations. In learning outcome 3, the provision of steam is examined for both power generation and process plant. Learning outcome 4 introduces learners to the applications and principles of operation of refrigeration plant and heat pumps.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand the use and applications of electrical supply systems

2 Be able to apply the gas laws to industrial compressors

3 Understand the provision of steam services for process and power use

4 Understand industrial applications of refrigerators and heat pumps.

Unit content

1 **Understand the use and applications of electrical supply systems**

IEE regulations: relationship to Health and Safety at Work Act 1974 and other legislation; codes of practice; regulations for given plant requirements; regulations regarding earthing and hazardous environments

Lighting: lighting fundamentals; SI units of lighting; efficacy; colour rendering; lamps and luminaires; stroboscopic effect; lighting circuits/layout and their design

Starting and speed control: classification of systems – manual and automatic DC starters, star-delta starter, autotransformer starter; speed control for AC and DC motors

Transformers: sub-stations; single-phase and three-phase transformers; transformer installation requirements; cooling; transformation ratio; magnetisation current; determination of values for transformer outputs

Power factor: causes; effect on cost of supplies; power factor correction

2 **Be able to apply the gas laws to industrial compressors**

Gas laws: Boyle's law, Charles' law, combined gas equation; characteristic gas equation; relationship between pressure-volume (pV) diagram and work; adiabatic, polytropic and isothermal work; compressor efficiency; effect of multi-staging; pressure and volume ratios

Industrial compressor systems: positive displacement eg reciprocating compressors, helical and spiral-lobe compressors, sliding vane compressors, two-impeller straight-lobe compressors and blowers; dynamic eg centrifugal compressors, axial compressors; associated equipment eg coolers, dryers, air receivers; safety factors eg Health and Safety at Work Act and related legislation, insurance requirements, safety fittings, diesel effect and other hazards

3 **Understand the provision of steam services for process and power use**

Process steam: wet and dry saturated steam; temperature control; enthalpy of evaporation; available energy; condensate collection; pipeline energy losses; lagging; feed tanks; effect of boundary layer on energy transfer; air contamination; pipe sizing; overall plant efficiencies for process

Power steam: superheated steam; steady flow energy equation applied to turbines; turbine efficiency; Rankine cycle with and without reheat; condensers; cooling towers; overall plant efficiency for power

Combined heat and power: back pressure system; pass out system; desuperheating; appropriateness of application to relative demand; comparisons of overall plant efficiency for combined heat and power; illustrative sketches eg Sankey diagrams, circuit layouts

4 **Understand industrial applications of refrigerators and heat pumps**

Reversed heat engines: reversed Carnot and Rankine cycles; vapour compression cycle; second law of thermodynamics; temperature-entropy diagrams; pressure-enthalpy diagrams; refrigeration tables and charts; refrigerant fluids; environmental effects

Refrigerators: refrigeration effect; coefficient of performance; refrigerator cycle

Heat pumps: heating effect; coefficient of performance; economics of heat pumps; pump cycles

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Understand the use and applications of electrical supply systems	1.1 use the relevant sections of the IEE regulations 1.2 design appropriate lighting circuits 1.3 classify starting and speed control mechanisms 1.4 determine appropriate values for transformer outputs 1.5 perform power factor correction calculations
LO2 Be able to apply the gas laws to industrial compressors	2.1 derive formulae with reference to the gas laws 2.2 apply the gas laws to an industrial compressor system
LO3 Understand the provision of steam services for process and power use	3.1 explain the requirements for process steam according to use 3.2 discuss the need for superheated steam for power use 3.3 determine overall plant efficiencies for process, power and combined heat and power systems 3.4 produce illustrative sketches of heat distribution in systems
LO4 Understand industrial applications of refrigerators and heat pumps	4.1 determine coefficient of performance, heating effect and refrigeration effect of reversed heat engines 4.2 use refrigeration tables and charts 4.3 sketch refrigerator and heat pump cycles 4.4 discuss the economics of heat pumps 4.5 explain the apparent contradiction between refrigeration cycles and the second law of thermodynamics.

Guidance

Links

This unit has links with *Unit 2: Engineering Science* and *Unit 43: Plant and Process Principles*.

Essential requirements

Centres will need to provide access to electrical and heat engine laboratory facilities.

Employer engagement and vocational contexts

Liaison with plant engineering and process companies would be useful to give learners the opportunity to witness industrial plant services first-hand.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering –
Issue 3 – November 2017

Unit 55: Instrumentation and Control Principles

Unit code: J/601/1417

Level: 4

Credit value: 15

Aim

The aim of this unit is to introduce learners to the principles and practice of instrumentation and control in process industries

Unit abstract

This unit is intended to give learners an appreciation of the principles of industrial instrumentation. The unit will also give learners an understanding of the techniques used in industrial process control and enable them to predict controller settings and make adjustments to achieve stability in such a control system.

Learners will investigate instrumentation systems terminology and the components that make up a system. Learners will then look at where instrumentation systems and controllers are applied in process control schemes. Finally, learners will examine the components of regulating units and their applications.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand instrumentation systems used in process control

2 Understand process control systems and controllers

3 Understand the use of regulating units.

Unit content

1 **Understand instrumentation systems used in process control**

System terminology: use of correct terminology eg accuracy, error, repeatability, precision, linearity, reliability, reproducibility, sensitivity, resolution, range, span, zero drift, hysteresis

Sensors/transducers: those used to measure pressure eg resistive, strain gauge, inductive, capacitive, semiconductor, ceramic, piezoelectric, linear variable differential transformer (LVDT); level eg conductivity, capacitive, ultrasonic, radar, nucleonic, load cells, radiometric, microwave, hydrostatic, sonar; flow eg ultrasonic, Coriolis, vortex, magnetic, differential pressure; temperature eg resistance, thermocouple, semiconductor, radiation pyrometers; displacement eg diffraction grating, lasers, variable resistance, ceramic, piezoelectric, LVDT

Transmitters/signal converters: current to pressure; pressure to current; microprocessor-based (smart); digital; analogue; optical; wireless

Transmission medium: pneumatic; hydraulic; electrical; fibre-optic; wireless

Signal conditioners: industry-standard devices; industry-standard signal ranges and conversion between them

2 **Understand process control systems and controllers**

Need for process control: quality; safety; consistency of product; optimum plant performance; human limitations; efficiency; cost; environmental

Process controller terminology: deviation; range; span; absolute deviation; control effect; set point; process variable; manipulated variable; measured variable; bumpless transfer; process variable tracking; direct and reverse acting; offset; on-off control; two step control; cycling; three-term control (proportional band, gain, proportional, proportional with integral, proportional with integral and derivative, proportional with derivative)

System terminology: distance velocity lags; transfer lags; multiple transfer lags; capacity; resistance; dead time; reaction rate; inherent regulation; open loop; closed loop; load; supply; static gain; dynamic gain; stability; loop gain

Tuning techniques: Zeigler-Nichols; continuous cycling; reaction curve; ¼ decay methods; tuning for no overshoot on start-up; tuning for some overshoot on start-up

Represent systems using: P and I diagrams; loop diagrams; wiring diagrams; constructing and using diagrams to appropriate standards

3 **Understand the use of regulating units**

Regulating unit terminology: body; trim; plug guide and seat; valve; stem; bonnet; packing gland; yoke; actuator; motor; stroke; direct and reverse action; air fail action; repeatability; CV; turndown; flow characteristics; linear, equal percentage, quick-opening, modified parabolic, split range

Characteristics of regulating units: dampers; power cylinders; louvres; valve positioners; valves (globe, ball, diaphragm, gate, double seated, 3-way, solenoid, split bodied, butterfly)

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Understand instrumentation systems used in process control	1.1 describe the terminology used in process measurements 1.2 evaluate a range of sensors and transducers with reference to manufacturers' terminology 1.3 explain the construction and operation of modern sensors used to measure pressure, level, temperature and flow 1.4 describe typical applications for the sensors examined 1.5 explain signal conditioning and transmission
LO2 Understand process control systems and controllers	2.1 explain the need for process control 2.2 describe process control terminology 2.3 determine the medium required for successful transmission 2.4 name sensors, conditioners and display units for a range of specific purposes 2.5 evaluate tuning techniques 2.6 describe the control actions required for different systems 2.7 represent systems using standard diagrams
LO3 Understand the use of regulating units	3.1 identify the main parts of a regulating unit 3.2 evaluate a regulating unit with reference to standard terminology, including manufacturers' specifications 3.3 select the plug characteristics required for a specified process 3.4 describe the characteristics of a range of regulating units 3.5 describe the use of valve positioners.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017

Guidance

Links

This unit is designed to be stand alone but has links to *Unit 48: Analytical and Chemical Composition Measurement* and *Unit 46: Plant Process and Control*.

Essential requirements

There are no essential requirements for this unit.

Employer engagement and vocational contexts

Visits to industrial installations will be of value to supplement learning activities and provide learners with a perspective on scale and application of process instrumentation and process control hardware.

Unit 57: Mechatronic Systems

Unit code:	F/601/1416
Level:	4
Credit value:	15

Aim

This unit will develop learners' understanding of a range of mechatronic systems that are used in industrial and domestic environments and enable them to produce specifications for mechatronic products.

Unit abstract

The material and topics covered in this unit will be broad-based to reflect the fact that mechatronics is, by its nature, multi-disciplinary and not confined to a single specialised area. The unit will encompass small, single component systems as well as larger systems integrating components from different engineering disciplines. It will develop a methodology that will allow learners to apply mechatronic design philosophy throughout the development cycle of a systems and products. The intention is to encourage the learner to recognise a system not as an interconnection of different parts but as an integrated module.

Learners will investigate the applications of mechatronics, considering the need for integration and the nature of mechatronic systems and products. Typical mechatronics components are examined by before learners look at the design steps and processes for mechatronic systems and mechatronic products.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand the applications of a range of mechatronic systems and products

2 Understand electro-mechanical models and components in mechatronic systems and products

3 Be able to produce a specification for a mechatronic system or mechatronic product

4 Be able to apply mechatronic design philosophies to carry out a design analysis.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017

Unit content

1 **Understand the applications of a range of mechatronic systems and products**

Discipline integration: need for systems to be designed in an integrated way rather than as a collection of unrelated yet interconnected constituent parts eg constraints in size and cost of components, reduction in cost of computing power, required reduction in process delays, compatibility of connection systems

Mechatronics systems: differentiate between systems that are mechatronics in nature and those that incorporate a number of different disciplines

Industrial and consumer examples of mechatronics systems: applications eg industrial robots, computer-based production and manufacture (CNC/CAM) machines, ATMs, transportation systems, 'fly by wire' aircraft, suspension control on road vehicles, brake- and steer-by-wire; auto-exposure, auto-focus cameras, vending machines, domestic appliances

2 **Understand electro-mechanical models and components in mechatronic systems and products**

Simple mathematical models: mechanical system building blocks; electrical system building blocks; electrical-mechanical analogies; fluid and thermal systems

Sensor technologies: sensor and actuator technologies for mechatronic system eg resistive, inductive, capacitive, optical/fibre-optic, wireless, ultrasonic, piezoelectric

Actuator technologies: electric motors; stepper motors; motor control; fluid power; integrated actuators and sensors; embedded systems

3 **Be able to produce a specification for a mechatronic system or mechatronic product**

Standards: standards eg appropriate British, European and international standards

Required sensor attributes: phenomena being sensed; interaction of variables and removal of undesired changes; proximity of sensor to measurand; invasiveness of the measurement and measurand; signal form; ergonomic and economic factors

Actuator and sensor technologies: selection of suitable sensor and actuator technologies for mechatronic systems and mechatronic products

Controllers: selection of appropriate computer control hardware for mechatronic systems and mechatronic products eg microprocessor, PLC, PC-based, PIC, embedded controllers

4 **Be able to apply mechatronic design philosophies to carry out a design analysis**

Designing: the steps in a design process; comparison between traditional design methods and those designs which are mechatronics driven

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Understand the applications of a range of mechatronic systems and products	1.1 identify mechatronic systems by their discipline integration 1.2 explain the need for system development in an integrated way 1.3 investigate mechatronic applications in consumer products and industrial processes
LO2 Understand electro-mechanical models and components in mechatronic systems and products	2.1 derive a mathematical model for 1st and 2nd order electrical and mechanical system 2.2 analyse analogies between the models of physically different systems 2.3 describe typical sensors and actuators for mechatronic systems and products
LO3 Be able to produce a specification for a mechatronic system or mechatronic product	3.1 produce a specification for a mechatronic system to meet current British Standards 3.2 select suitable sensor and actuator technologies for a mechatronic system 3.3 specify appropriate computer control hardware for a mechatronic system
LO4 Be able to apply mechatronic design philosophies to carry out a design analysis	4.1 carry out a design analysis on a system or product using mechatronic design philosophies 4.2 compare a system or product which has been designed employing traditional methods with one employing mechatronic methods.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017

Guidance

Links

This unit can be linked to *Unit 5: Electrical and Electronic Principles* and *Unit 32: Industrial Robot Technology.*

Essential requirements

Centres will need to provide access to a range of case studies, highlighting the use of mechatronic design philosophies.

Employer engagement and vocational contexts

Learners should be encouraged to review processes in their workplace in order to demonstrate the efficacy of adopting a mechatronics approach.

Unit 58: Microprocessor Systems

Unit code: T/601/1414

Level: 4

Credit value: 15

Aim

This unit will develop learners' understanding of microprocessor-based systems and their use in instrumentation, control or communication systems.

Unit abstract

This unit will develop learners' understanding of the practical aspects of device selection and the interfacing of external peripheral devices. Learners will also study the key stages of the development cycle – specify, design, build, program, test and evaluate.

The first learning outcome requires learners to investigate and compare the applications of microprocessor-based systems. Following this, learners will experience and develop software designs and write programs for a microprocessor-based system. The final learning outcome considers the design of programmable interface devices such as UARTs, PPIs, I/O mapped devices and memory-mapped devices. At this point, learners should be able to carry out the design, build, program and test of a programmable interface. This will include the selection and use of devices and the writing and testing of suitable software in assembler or high-level language.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand microprocessor-based systems

2 Be able to design software, write and test programs for a microprocessor-based system

3 Be able to design and build programmable interface devices.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017 © Pearson Education Limited 2017

Unit content

1 **Understand microprocessor-based systems**

Microprocessor device families: comparison of three families based on speed, cost, input/output (I/O) facilities, instruction set, physical size

Applications: control systems eg car engine management, robotics, distributed control systems, coin-operated machines, printers; instrumentation systems eg data acquisition and logging systems, indicator display systems, 'intelligent' panel instruments, test equipment; communication systems eg modems, radio transmitters, radar systems; commercial systems eg electronic funds transfer at point of sale systems (EFTPOS), electronic bank teller machines, hand-held stock loggers, personal computers

2 **Be able to design software, write and test programs for a microprocessor-based system**

Design software to a given specification: algorithms in the form of a structure chart showing actions and conditions or in pseudo code (structured English)

Write programs: for applications requiring interfacing to external devices eg lights, switches, motors, heaters, keypads, liquid crystal displays (LCD) and light emitting diode (LED) displays, printers, analogue to digital (ADCs) and digital to analogue (DACs) converters; use of assemblers and high-level language compilers eg C, Visual BASIC, Java

Test software compliance with specification: suitable test data (inputs and expected outputs) should be prepared prior to running programs and results of the tests should be documented; use of software debugging tools eg Integrated Development Environment (IDE), In-Circuit Emulation (ICE), simulators

3 **Be able to design and build programmable interface devices**

Programmable interface devices: evaluation of serial and parallel interfaces eg UARTs, PPIs, I/O mapped devices, memory-mapped devices; and control signals eg interrupts; polling; handshaking; port current rating

Design, build, programme and test: a programmable interface; select and use devices; write and test suitable software in assembler or high-level language

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Understand microprocessor-based systems	1.1 compare types of microprocessor device families 1.2 evaluate three typical applications of microprocessor-based systems
LO2 Be able to design software, write and test programs for a microprocessor-based system	2.1 design software to a given specification using a structured design technique 2.2 write programs to implement designs using an appropriate computer language 2.3 test software to ensure it meets the given specification
LO3 Be able to design and build programmable interface devices	3.1 evaluate and choose programmable interface devices for a particular situation 3.2 design, build, program and test an interface for an external device to a microprocessor-based system.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017

Guidance

Links

This unit may be linked with *Unit 66: Electrical*, *Electronic and Digital Principles.*

Essential requirements

Learners will need access to a microprocessor-based development system. Centres will also need to provide software development systems (personal computers/workstations/terminals capable of running program development software), a software-editor and assembler/compiler debugging tools for the target processor.

The software development system and the target microprocessor-based system may be the same (for example a personal computer).

Employer engagement and vocational contexts

The delivery of this unit will benefit from centres establishing strong links with employers willing to contribute to the delivery of teaching, work-based placements and/or detailed case study materials.

Unit 59: Advanced Mathematics for Engineering

Unit code: K/601/1412

Level: 5

Credit value: 15

Aim

This unit aims to provide the analytical knowledge necessary for studying engineering to degree level and will provide the more advanced knowledge required for a range of careers in engineering.

Unit abstract

This unit will enable learners to develop further techniques for the modelling and solution of engineering problems.

Learners will review methods for standard power series and use them to solve ordinary differential equations. Numerical methods are then considered before both methods are used to model engineering situations and determine solutions to those equations.

Laplace transforms are introduced in learning outcome 2 and their use in solving first and second order differential equations together with the solution of simultaneous equations.

In learning outcome 3, Fourier coefficients are determined to represent periodic functions as infinite series and then the Fourier series approach is applied to the exponential form to model phasor behaviour. The final part of this learning outcome involves using the Fourier series to model engineering situations and solve problems.

Learning outcome 4 reviews partial differentiation techniques to solve rates of change problems and problems involving stationary values. Also in this learning outcome, direct partial integration and the separation of variables methods are used to solve partial differential equations. Finally, partial differential equations are used to model engineering situations and solve problems.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017 © Pearson Education Limited 2017

Learning outcomes

On successful completion of this unit a learner will:

1. Be able to analyse and model engineering situations and solve engineering problems using series and numerical methods for the solution of ordinary differential equations
2. Be able to analyse and model engineering situations and solve engineering problems using Laplace transforms
3. Be able to analyse and model engineering situations and solve engineering problems using Fourier series
4. Be able to analyse and model engineering situations and solve engineering problems using partial differential equations.

Unit content

1 **Be able to analyse and model engineering situations and solve engineering problems using series and numerical methods for the solution of ordinary differential equations**

Power series: review of methods for standard series, Maclaurin's series and Taylor's series

Power series methods: methods eg higher differential coefficients and Leibnitz's theorem, recurrence relations, Leibnitz–Maclaurin method, Frobenius method, engineering use of Bessel's equation and Legendre equation, Bessel functions of the first and second kind, Legendre's equation and polynomials

Numerical methods: restrictions on the analytical solution of differential equations; typical methods eg Taylor's series, solution of first order differential equations, Euler's method, improved Euler method, Runge–Kutta method

Engineering situations: model engineering situations and solve problems using ordinary differential equations eg vibration, thermofluids and heat transfer, mechanics of solids, electrical systems, information systems

2 **Be able to analyse and model engineering situations and solve engineering problems using Laplace transforms**

Laplace transform: use of Laplace transform; transforms of standard functions; first shift theorem; inverse transforms and tables of inverse transforms; transforms using partial fractions; poles and zeros; solution of first and second order differential equations using Laplace transforms; solution of simultaneous differential equations; initial and final value problems

Engineering situations: model engineering situations and solve problems using Laplace transforms eg electrical circuits in the *s*-domain, modelling and analysis of closed loop control systems, response of first and second order systems, servomechanisms, systems engineering, systems stability analysis, automatic flight control systems, design of feedback systems – root locus plots, Nyquist and Bode plots, Nichols charts

3 **Be able to analyse and model engineering situations and solve engineering problems using Fourier series**

The Fourier series: sinusoidal and non-sinusoidal waveforms; periodic functions; harmonics; the Fourier series; Fourier coefficients; series for common wave-forms; odd and even functions and their products; half-range series; non-periodic functions and their half-range series

The exponential form: complex notation; symmetry relationship; frequency spectrum and phasors

Engineering situations: model engineering situations and solve problems using Fourier series eg electric circuit analysis, root mean square values, power and power factors, numerical integration and numerical harmonic analysis

4 **Be able to analyse and model engineering situations and solve engineering problems using partial differential equations**

Partial differentiation: review of partial differentiation techniques; partial differentiation and rates of change problems; change of variables; stationary values and saddle points

Partial differential equations: definition of partial differential equations; partial integration; solution by direct partial integration; initial conditions and boundary conditions; solution by separation of variables

Engineering situations: model engineering situations and solve problems using partial differential equations eg the wave equation and its application to vibration, the heat conduction equation, the Laplace equation and its application to temperature and potential

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can**:
LO1 Be able to analyse and model engineering situations and solve engineering problems using series and numerical methods for the solution of ordinary differential equations	1.1 determine power series values for common scientific and engineering functions 1.2 solve ordinary differential equations using power series methods 1.3 solve ordinary differential equations using numerical methods 1.4 model engineering situations, formulate differential equations and determine solutions to these equations using power series and numerical methods
LO2 Be able to analyse and model engineering situations and solve engineering problems using Laplace transforms	2.1 determine Laplace transforms and their inverse using tables and partial fractions 2.2 solve first and second order differential equations using Laplace transforms 2.3 model and analyse engineering systems and determine system behaviour using Laplace transforms
LO3 Be able to analyse and model engineering situations and solve engineering problems using Fourier series	3.1 determine Fourier coefficients and represent periodic functions as infinite series 3.2 apply the Fourier series approach to the exponential form and model phasor behaviour 3.3 apply Fourier series to the analysis of engineering problems 3.4 use numerical integration methods to determine Fourier coefficients from tabulated data and solve engineering problems using numerical harmonic analysis
LO4 Be able to analyse and model engineering situations and solve engineering problems using partial differential equations	4.1 solve rates of change problems and problems involving stationary values using partial differentiation 4.2 solve partial differential equations using direct partial integration and separation of variables methods 4.3 model and analyse engineering situations using partial differential equations.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017

Guidance

Links

This unit is intended to link with and extend the knowledge gained from studying *Unit 35: Further Analytical Methods for Engineers*.

Essential requirements

There are no essential requirements for this unit.

Employer engagement and vocational contexts

Delivery of this unit will benefit from centres establishing strong links with employers willing to contribute to the delivery of teaching, work-based placements and/or detailed case study materials.

Unit 60: Dynamics of Machines

Unit code: H/601/1411

Level: 4

Credit value: 15

Aim

This unit will deepen learners' knowledge of the principles and techniques used in the design of machine elements.

Unit abstract

This unit will develop learners' understanding of the parameters and characteristics of mechanical systems. Learning outcome 1 is concerned with the characteristics of a wider range of power transmission elements. Learning outcome 2 will introduce learners to an in-depth analysis of some common mechanical systems using both analytical and graphical techniques. Learning outcome 3 is concerned with mechanical vibrations and in particular the transient and steady-state response of mass-spring systems to disturbing forces.

Learning outcomes

On successful completion of this unit a learner will:

1 Be able to determine the kinetic and dynamic parameters of power transmission system elements

2 Be able to determine the kinetic and dynamic parameters of mechanical systems

3 Be able to determine the behavioural characteristics of translational and rotational mass-spring systems.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017

Unit content

1 **Be able to determine the kinetic and dynamic parameters of mechanical power transmission system elements**

Gears: gear geometry; velocity ratios of simple, compound and epicyclic gear trains; acceleration of geared systems

Screw drives: motion on an inclined plane; efficiency of square-threaded lead screws and screw jacks

Flywheels: turning moment diagrams for reciprocating engines and presses; determination of required flywheel moment of inertia to satisfy specified operating conditions

Universal couplings: Hooke's joint; constant velocity joint; conditions for a constant velocity ratio

2 **Be able to determine the kinetic and dynamic parameters of mechanical systems**

Cams: radial plate and cylindrical cams; follower types; profiles to give uniform velocity; uniform acceleration and retardation and simple harmonic motion outputs; output characteristics of eccentric circular cams, circular arc cams and cams with circular arc and tangent profiles with flat-faced and roller followers

Plane mechanisms: determination of instantaneous output velocity for the slider-crank mechanism, the four-bar linkage and the slotted link and Whitworth quick return motions; construction of velocity vector diagrams; use of instantaneous centre of rotation

Resultant acceleration: centripetal, tangential, radial and Coriolis components of acceleration in plane linkage mechanisms; resultant acceleration and inertia force; use of Klein's construction for the slider crank mechanism

Gyroscopic motion: angular velocities of rotation and precession; gyroscopic reaction torque; useful applications eg gyro-compass and gyro-stabilisers

3 **Be able to determine the behavioural characteristics of translational and rotational mass-spring systems**

Natural vibrations: mass-spring systems; transverse vibrations of beams and cantilevers; torsional vibrations of single and two-rotor systems; determination of natural frequency of vibration; whirling of shafts

Damped vibrations: representative second-order differential equation for mass-spring system with damping; transient response of a mass-spring system to an impulsive disturbance; degrees of damping; frequency of damped vibrations; logarithmic decrement of amplitude

Forced vibrations: representative second-order differential equation for a damped mass-spring system subjected to a sinusoidal input excitation; transient and steady state solutions; amplitude and phase angle of the steady state output; effect of damping ratio; conditions for resonance

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can**:
LO1 Be able to determine the kinetic and dynamic parameters of mechanical power transmission system elements	1.1 analyse geared systems to determine velocity ratio and required accelerating torque 1.2 determine the operating efficiency of screw jacks and lead screws 1.3 analyse turning moment diagrams for reciprocating engines and presses to determine the required flywheel parameters for specific operating conditions 1.4 analyse the characteristics of Hooke's joints and constant velocity joints and recognise the conditions for a constant velocity ratio
LO2 Be able to determine the kinetic and dynamic parameters of mechanical systems	2.1 determine the output motion of radial plate and cylindrical cams 2.2 determine the velocities and accelerations of points within plane mechanisms and the associated inertia forces 2.3 analyse systems in which gyroscopic motion is present to determine the magnitude and effect of gyroscopic reaction torque
LO3 Be able to determine the behavioural characteristics of translational and rotational mass-spring systems	3.1 determine the natural frequency of vibration in translational and rotational mass-spring systems 3.2 determine the critical whirling speed of shafts 3.3 determine the transient response of damped mass-spring systems when subjected to a disturbance 3.4 determine the steady state response of damped mass-spring systems when subjected to sinusoidal excitation.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017 © Pearson Education Limited 2017

Guidance

Links

This unit is intended to provide progression from *Unit 2: Engineering Science* and *Unit 4: Mechanical Principles*.

Essential requirements

There are no essential requirements for this unit.

Employer engagement and vocational contexts

Delivery of this unit will benefit from centres establishing strong links with employers willing to contribute to the delivery of teaching, work-based placements and/or detailed case study materials.

Unit 61: Engineering Thermodynamics

Unit code: D/601/1410

Level: 5

Credit value: 15

Aim

This unit will extend learners' knowledge of heat and work transfer. It will develop learners' understanding of the principles and laws of thermodynamics and their application to engineering thermodynamic systems.

Unit abstract

This unit will build on learners' understanding of polytropic expansion/compression processes, the first law of thermodynamics and the concepts of closed and open thermodynamic systems. Learners are then introduced to the second law of thermodynamics and its application in the measurement and evaluation of internal combustion engine performance. This is followed by measurement and evaluation of air compressor performance. Finally, learners will develop an understanding of the layout and operation of steam and gas turbine power plants.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand the parameters and characteristics of thermodynamic systems

2 Be able to evaluate the performance of internal combustion engines

3 Be able to evaluate the performance of reciprocating air compressors

4 Understand the operation of steam and gas turbine power plant.

Unit content

1 **Understand the parameters and characteristics of thermodynamic systems**

Polytropic processes: general equation $pv^n = c$, relationships between index 'n' and heat transfer during a process; constant pressure and reversible isothermal and adiabatic processes; expressions for work flow

Thermodynamic systems and their properties: closed systems; open systems; application of first law to derive system energy equations; properties; intensive; extensive; two-property rule

Relationships: $R = c_p - c_v$ and $\gamma = c_p/c_v$

2 **Be able to evaluate the performance of internal combustion engines**

Second law of thermodynamics: statement of law; schematic representation of a heat engine to show heat and work flow

Heat engine cycles: Carnot cycle; Otto cycle; Diesel cycle; dual combustion cycle; Joule cycle; property diagrams; Carnot efficiency; air-standard efficiency

Performance characteristics: engine trials; indicated and brake mean effective pressure; indicated and brake power; indicated and brake thermal efficiency; mechanical efficiency; relative efficiency; specific fuel consumption; heat balance

Improvements: turbocharging; turbocharging and intercooling; cooling system and exhaust gas heat recovery systems

3 **Be able to evaluate the performance of reciprocating air compressors**

Property diagrams: theoretical pressure-volume diagrams for single and multi-stage compressors; actual indicator diagrams; actual, isothermal and adiabatic compression curves; induction and delivery lines; effects of clearance volume

Performance characteristics: free air delivery; volumetric efficiency; actual and isothermal work done per cycle; isothermal efficiency

First law of thermodynamics: input power; air power; heat transfer to intercooler and aftercooler; energy balance

Faults and hazards: effects of water in compressed air; causes of compressor fires and explosions

4 **Understand the operation of steam and gas turbine power plant**

Principles of operation: impulse and reaction turbines; condensing; pass-out and back pressure steam turbines; single and double shaft gas turbines; regeneration and re-heat in gas turbines; combined heat and power plants

Circuit and property diagrams: circuit diagrams to show boiler/heat exchanger; superheater; turbine; condenser; condenser cooling water circuit; hot well; economiser/feedwater heater; condensate extraction and boiler feed pumps; temperature-entropy diagram of Rankine cycle

Performance characteristics: Carnot, Rankine and actual cycle efficiencies; turbine isentropic efficiency; power output; use of property tables and enthalpy-entropy diagram for steam

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering –

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can**:
LO1 Understand the parameters and characteristics of thermodynamic systems	1.1 evaluate polytropic process parameters 1.2 explain the operation thermodynamic systems and their properties 1.3 apply the first law of thermodynamics to thermodynamic systems 1.4 determine the relationships between system constants for an ideal gas
LO2 Be able to evaluate the performance of internal combustion engines	2.1 apply the second law of thermodynamics to the operation of heat engines 2.2 evaluate theoretical heat engine cycles 2.3 evaluate the performance characteristics of spark ignition and compression ignition internal combustion engines 2.4 discuss methods used to improve the efficiency of internal combustion engines
LO3 Be able to evaluate the performance of reciprocating air compressors	3.1 evaluate property diagrams for compressor cycles 3.2 determine the performance characteristics of compressors 3.3 apply the first law of thermodynamics to compressors 3.4 identify compressor faults and hazards
LO4 Understand the operation of steam and gas turbine power plant	4.1 explain the principles of operation of steam and gas turbines 4.2 illustrate the functioning of steam power plant by means of circuit and property diagrams 4.3 determine the performance characteristics of steam power plant.

Guidance

Links

This unit has links with *Unit 1: Analytical Methods for Engineers*, *Unit 2: Engineering Science* and *Unit 41: Fluid Mechanics*.

Essential requirements

Laboratory facilities will need to be available for the investigation of the properties of working fluids, internal combustion engines and compressor performance.

Employer engagement and vocational contexts

Liaison with industry can help centres provide access to relevant industrial laboratory facilities, engines, compressors and related plant.

Where possible, work-based experience should be used to provide practical examples of the characteristics of thermodynamic systems.

A visit to a power station will be of value to support delivery of learning outcome 4.

Unit 62: Strengths of Materials

Unit code: K/601/1409

Level: 5

Credit value: 15

Aim

This unit will enable learners' to use stress analysis techniques to determine the behavioural characteristics of engineering components and materials.

Unit abstract

This unit will introduce learners to the theoretical and experimental methods of complex stress analysis, together with the theories of elastic failure. Appropriate use of these can be made throughout the unit to determine operational factors of safety. Learners will investigate the theoretical behaviour of structural members under load and will verify the characteristics by experimental testing. They will then analyse loaded structural members from considerations of strain energy and again carry out experimental verification of the analysis.

Learning outcomes

On successful completion of this unit a learner will:

1 Be able to determine the behavioural characteristics of engineering components subjected to complex loading systems

2 Be able to determine the behavioural characteristics of loaded beams, columns and struts

3 Be able to determine the behavioural characteristics of loaded structural members by the consideration of strain energy.

Unit content

1 **Be able to determine the behavioural characteristics of engineering components subjected to complex loading systems**

Complex stress: analysis of two-dimensional stress systems eg determination of principal planes and stresses, use of Mohr's stress circle; combined torsion and thrust; combined torsion and bending

Complex strain: Mohr's strain circle; experimental strain analysis using electrical resistance strain gauges

Theories of elastic failure: maximum principal stress theory; maximum shear stress theory; strain energy theory and maximum principal strain theory

2 **Be able to determine the behavioural characteristics of loaded beams, columns and struts**

Simply supported beams: use of Macaulay's method to determine the support reactions, slope and deflection due to bending in cantilevers and simply supported beams with combined concentrated and uniformly distributed loads

Reinforced concrete beams: theoretical assumptions; distribution of stress due to bending

Columns: stress due to asymmetrical bending; middle third rule for rectangular section columns and walls; middle quarter rule for circular section columns

Struts: end fixings; effective length; least radius of gyration of section; slenderness ratio; Euler and Rankine-Gordon formulae for determination of critical load

3 **Be able to determine the behavioural characteristics of loaded structural members by the consideration of strain energy**

Strain energy: strain energy stored as a result of direct loading, shear loading, bending and torsion

Elastic deflections: elastic deflection of struts and ties when subjected to gradually applied loads; elastic deflection at the point of loading for cantilevers and simply supported beams when subjected to a single gradually applied load; application of Castigliano's theorem to determine deflection eg beams, brackets, portal frames and curved bars when subjected to gradually applied loads; elastic deflection of torsion bars and transmission shafts subjected to a gradually applied torque

Shock loading: elastic deflection and stress induced in struts and ties when subjected to suddenly applied loads and impact loads

Outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can**:
LO1 Be able to determine the behavioural characteristics of engineering components subjected to complex loading systems	1.1 analyse two-dimensional stress systems making appropriate use of Mohr's stress circle 1.2 carry out experimental strain analysis using electrical resistance strain gauges 1.3 apply the appropriate theory of elastic failure to loaded components to determine operational factors of safety
LO2 Be able to determine the behavioural characteristics of loaded beams, columns and struts	2.1 determine the support reactions, slope and deflection of simply supported beams 2.2 determine the distribution of stress in the materials of reinforced concrete beams 2.3 determine the stress distribution in columns and walls which are subjected to asymmetrical bending 2.4 determine the appropriate critical load for axially loaded struts 2.5 carry out tests to validate critical load calculations
LO3 Be able to determine the behavioural characteristics of loaded structural members by the consideration of strain energy	3.1 determine the strain energy stored in a member due to direct loading, shear loading, bending and torsion 3.2 determine the elastic deflection of loaded members making appropriate use of Castigliano's theorem 3.3 carry out tests to validate deflection calculations 3.4 predict the effects of shock loading on struts and ties.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017

Guidance

Links

This unit is intended to provide progression from *Unit 2: Engineering Science* and *Unit 4: Mechanical Principles*.

Essential requirements

Centres need to provide access to laboratory facilities so that learners can investigate the effects of loading on structural members and engineering components.

Employer engagement and vocational contexts

The delivery of this unit will benefit from centres establishing strong links with employers willing to contribute to the delivery of teaching, work-based placements and/or detailed case study materials.

Unit 63: Electrical Power

Unit code:	H/601/1408
Level:	4
Credit value:	15

Aim

This unit will develop learners' understanding of electrical power systems and power distribution and the advantages and disadvantages of alternative energy sources.

Unit abstract

Our modern world increasingly relies upon electrical power to supply our industries, commercial centres and homes with a convenient, flexible and reliable source of energy.

To meet the client's expectations, electrical energy must be provided at a reasonable cost and transmitted to the point of need, at the appropriate voltage and current levels. The client's utilisation of the energy source needs to be appropriate, without undue complexity, to facilitate energy generation and transmission.

This unit takes the learner through the complex process of analysing three-phase systems with consideration being given to harmonics and their effects. The methods of power distribution through the National Grid are then discussed with final economic considerations taken into account to enhance generation, transmission and distribution, with acceptable costs to clients.

Throughout their working careers, modern engineers will have to consider new technologies and be able to evaluate the options available to make appropriate selections. With our global resources of fossil energy reserves decreasing and concerns over protecting the environment growing, alternative sources of energy are considered. Evaluative considerations will be made to inform the engineer of the issues associated with this topic, which may need to be considered far more at local and regional levels. Additionally, self-generation of electrical energy is now possible for a broad range of users throughout the world, utilising local environmental facilities.

Learning outcomes

On successful completion of this unit a learner will:

1 Be able to analyse three-phase systems

2 Understand the sources and effects of harmonics in power systems

3 Understand methods of power distribution

4 Understand the economics of components, power systems and alternative energy.

Unit content

1 **Be able to analyse three-phase systems**

Fault free three-phase systems: use of j-notation (complex numbers) in the analysis of un-faulted three-phase systems eg phase sequence, balanced star supply, balanced delta supply, 4 wire and 3 wire balanced star loads, unbalanced 4 wire star loads, balanced delta loads, unbalanced delta loads

Measurement of power: methods of determining power in three-phase balanced and unbalanced systems eg Blondel's theorem, integrated three-phase wattmeters, real power, reactive power, apparent power

Faulted three-phase systems: connection errors and faults eg loss of neutral, loss of one line, reversed supply phase, unbalanced supply voltages, reversed phase sequence

Three-phase transformers: construction eg three single-phase transformers, shell and core type; connections eg terminal marking BS 171, phasor diagrams, star, delta, zig-zag, clock number and group, parallel operation

Characteristics: methods of operation of a three-phase induction motor; starting methods; current; torque and control techniques; torque speed characteristics of motor and load; steady state; operating point

Load dynamics: eg dynamic stability, crawling, inertia, friction, acceleration time

2 **Understand the sources and effects of harmonics in power systems**

Harmonics: pitch; wave theory; natural frequencies, harmonic series; resonance

Sources of harmonics: transformer magnetising current; direct current power supply units; general non-linear loads

Effects of harmonic: increased root-mean-square currents; zero sequence; triple-n neutral currents in star systems; triple-n currents trapped in delta transformers; overheating in neutral; overheating in motors and transformers; failure of power factor correction capacitors; harmonic resonance; skin effect losses

Mitigation of harmonics: methods of mitigation such as oversized neutral, de-rating, circuit separation, K factor and factor K, isolation transformers, passive and active filters, total harmonic distortion, standards G5/4

3 **Understand methods of power distribution**

Topology: system integrity; radial feeders; parallel feeders; open and closed rings; inter-connector

Operating parameters: load distribution eg radial, ring, parallel feeders, voltage and current profiles, permissible, voltage drop, power losses, power efficiency

4 **Understand the economics of components, power systems and alternative energy**

Economics: economic considerations eg power factor correction, energy tariffs, Kelvin's law, compact fluorescent lighting; comparisons of single and three-phase systems; high and low efficiency motors

Alternative energy: geothermal; solar; wind; water; biomass eg liquid biofuel, solid biomass, biogas

Evaluation: cost (capital, operating); efficiency; energy storage; environmental impact; feasibility on large and small scale

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
1 Be able to analyse three-phase systems	1.1 solve problems involving fault free three-phase systems 1.2 measure power in three-phase systems 1.3 solve problems involving faulted three-phase systems 1.4 describe three-phase transformers 1.5 describe the characteristics of a three-phase induction motor 1.6 assess the effect of load dynamics
2 Understand the sources and effects of harmonics in power systems	2.1 identify typical sources of harmonics in a power system 2.2 explain the effects of harmonics in power systems 2.3 evaluate at least four different methods of mitigation of harmonics
3 Understand methods of power distribution	3.1 compare different power system topologies 3.2 analyse the operating parameters of a radial and a ring distribution system
4 Understand the economics of components, power systems and alternative energy	4.1 compare the economics of single-phase and three-phase distribution 4.2 compare and evaluate the different forms of alternative energies.

Guidance

Links

This unit may be linked with *Unit 1: Analytical Methods for Engineers* and *Unit 5: Electrical and Electronic Principles*. *Unit 35: Further Analytical Methods for Engineers* would support the use of j-notation (complex numbers) required in learning outcome 1.

Essential requirements

Learners will need access to appropriate laboratory and test equipment (for example three-phase supply, transformer and loads, three-phase induction motor and starters, power analyser, etc).

Employer engagement and vocational contexts

Delivery of this unit would benefit from visits to a power station or wind farm or the attendance of guest speaker(s) with relevant experience of power generation and transmission.

Unit 64: Electrical and Electronic Measurement and Testing

Unit code: Y/601/1406

Level: 4

Credit value: 15

Aim

This unit will develop the knowledge and skills required to perform complex measurement and test procedures on electrical and electronic systems.

Unit abstract

Throughout their working lives, technicians and engineers in the electrical and electronic field of engineering make use of a comprehensive range of test and measurement instruments in order to perform their duties. This unit will develop the underpinning knowledge and skills required to perform complex measurement and test procedures in a wide range of engineering sectors.

Test and measurement procedures require the learner to consistently and accurately perform the task, at reasonable costs, to be able to convert results to suitable formats or conduct monitoring performance purposes. The development of such skills in using test equipment will further lead to abilities in troubleshooting electronic equipment or verifying theoretical concepts.

This unit takes the learner through a logical process of development by firstly considering the concepts of a measurement system and the associated terminology. Learners will adopt a hands-on approach by using different methods (for example spreadsheets) to solve problems relating to data that has been measured. Learners are then introduced to a variety of test equipment and shown the correct choice and use for a particular application. Finally, learner will examine the principles and techniques used in data acquisition.

Learning outcomes

On successful completion of this unit a learner will:

1 Be able to analyse a measurement system and solve problems relating to the characteristics of a signal

2 Be able to analyse the principles and techniques employed in measurement

3 Be able to select and use test equipment to measure a range of signals

4 Be able to apply the principles and techniques used in data acquisition systems.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017 © Pearson Education Limited 2017

Unit content

1 **Be able to analyse a measurement system and solve problems relating to the characteristics of a signal**

Measurement systems and terms: system eg transducers; transmission systems; instruments; terms eg response of the systems, transfer function, impulse response, frequency response, dynamic range; block diagram of typical measurement/transmission systems

Transmission systems: coaxial; twisted pair; flat cable; fibre-optic; attenuation, phase change and frequency response; noise and noise reduction; comparison of different types of transmission systems

Characteristics of signals: continuous signals; discrete signals; frequency and period; peak; average; effective value; phase shift; amplitude; peak to peak; time domain; frequency domain; Fourier series of signals

2 **Be able to analyse the principles and techniques employed in measurement**

Characteristics of data: error/accuracy/precision; significant digits; rounding numbers; types of errors; statistics; solution of problems relating to data that has been measured

Graphical techniques: linear graphs; polar graphs; logarithmic graphs; solution of problems using graphical analytical techniques eg interpretation of graphs; finding the best-fit straight line; use of spreadsheets

3 **Be able to select and use test equipment to measure a range of signals**

Selection and use of test equipment: specify the correct equipment to measure a signal; practical use and description of test equipment

Test equipment: specifications of equipment; operation of equipment eg oscilloscopes, meters, signal generators, counters, logic analysers, spectrum analysers; block diagrams to explain the operation of selected test equipment

4 **Be able to apply the principles and techniques used in data acquisition systems**

Acquisition systems: comparison of types of system interfaces (analogue to analogue, analogue to digital, digital to digital); identification of system elements eg data acquisition, data analysis and data presentation; identification of hardware and software required to capture data from an item under test

Application: overview of data acquisition systems eg block diagram of typical system and explanation of its operation; input section eg transducers, signal conditioning and multiplexer; sampling methods; output filtering and corrections (sin x/x); errors; A/D conversion; CPU and I/O devices; comparison of data recording methods eg graphic, magnetic; operation of bus structures; block diagrams of typical structures and comparison of types of bus structures in use; control of data lines; application of a data acquisition system to determine the performance of an item under test; analysis of results from a system

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Be able to analyse a measurement system and solve problems relating to the characteristics of a signal	1.1 analyse a measurement system 1.2 solve problems relating to the characteristics of signals 1.3 compare different types of transmission systems
LO2 Be able to analyse the principles and techniques employed in measurement	2.1 solve problems relating to data that has been measured 2.2 solve problems using graphical techniques 2.3 solve problems using spreadsheets
LO3 Be able to select and use test equipment to measure a range of signals	3.1 describe the operation of items of test equipment 3.2 select and use items of test equipment to measure signals
LO4 Be able to apply the principles and techniques used in data acquisition systems	4.1 identify the hardware and software required to capture data from an item under test 4.2 investigate the operation of a data acquisition system 4.3 apply a data acquisition system to determine the performance of an item under test 4.4 analyse the results obtained from the data acquisition.

Guidance

Links

This unit can be linked to *Unit 5: Electrical and Electronic Principles*.

Essential requirements

A range of laboratory test equipment (for example L-C-R boxes, waveform generators, oscilloscopes, waveform analysers, and test meters, etc) will need to be available, along with appropriate data acquisition, recording and analytical software packages.

Employer engagement and vocational contexts

Delivery of this unit will benefit from centres establishing strong links with employers willing to contribute to the delivery of teaching, work-based placements and/or detailed case study materials.

Unit 65: Utilisation of Electrical Energy

Unit code: A/601/1396

Level: 4

Credit value: 15

Aim

This unit aims to develop learners' understanding of the underlying technology involved in the utilisation of electrical energy in some of the more important areas of electrical engineering.

Unit abstract

Electrical energy needs to be used efficiently in order to reduce wastage, especially given the future limitation of fossil fuels and growing environmental concerns.

The selection of power transformers with their varied characteristics will assist distribution and provide electrical energy at usable voltage and current levels to meet client demands.

As an integrated component, the electrical system needs to be protected at its various stages of transmission and distribution against excessive demands and faults that may occur.

The uses of electrical energy are wide and varied but in many ways they can be categorised into three areas: lighting systems, general power consumption, and motors.

The first learning outcome considers the operation of power transformers, including construction and operating principles and star-star/delta-star/delta-zigzag connections.

Learning outcome 2 looks at circuit protection systems such as over-current and earth-fault protection.

Lighting systems are considered in learning outcome 3 with a look at the different types of lighting available followed by an explanation of how to design and plan a scheme for a small development.

The different types of tariff structures available are studied in learning outcome 4, together with calculations to evaluate the cost of running a system.

Finally, learning outcome 5 examines the operation of the different types of polyphase induction motor, operation principles, starting methods and speed control.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand the operation of power transformers

2 Understand the applications of circuit protection for distribution and installation systems

3 Understand the design and construction of lighting systems

4 Be able to determine the cost of energy used in a system in order to be energy efficient

5 Understand the operation of a polyphase induction motor.

Unit content

1 **Understand the operation of power transformers**

Construction: shell and core types

Operating principles: derive the equivalent circuit for an ideal transformer on load; phasor diagram for an ideal transformer on load; identify the no-load losses; derive the equivalent circuit to represent no-load losses, leakage reactance, winding impedance; derive the complete equivalent circuit; components of the equivalent circuit referred to one winding; phasor diagram for the loaded transformer; voltage regulation; approximate formula for voltage regulation; calculation of voltage regulation, losses on load, efficiency of transformer; calculation of efficiency under load conditions, effects of load changes on losses, load conditions for maximum efficiency; calculation of maximum efficiency

Connections: star-star; delta-star; delta-zigzag

2 **Understand the applications of circuit protection for distribution and installation systems**

Over-current protection devices: construction of oil, vacuum and airblast circuit breakers, high rupture capacity fuse, overcurrent relay and miniature circuit breaker

Operating principles: characteristics and circuit positions of over-current relays, high rupture capacity fuse and miniature circuit breaker; calculation of ‘time to clear’ over-current faults; discriminations

Earth fault protection devices: construction of earth fault relay and residual current circuit breaker; performance requirements of earth fault protection; principle of operation and characteristics of earth fault relays and residual current circuit breaker; position in circuit; calculation of ‘time to clear’ earth faults; discrimination

3 **Understand the design and construction of lighting systems**

Common lamp types: low pressure mercury; high pressure mercury; low pressure sodium; high pressure sodium; fluorescent and halogen

Lighting design: quality of light; control of glare; luminance distribution; consistency of lighting levels; interior lighting design codes; lighting for visual tasks; emergency lighting

Light scheme: produce a scheme for one of the following developments or equivalent given the appropriate plans (eg small commercial development to involve roads, tunnel, pedestrian areas and car parks; small supermarket; administration office of a college, including computer stations)

4 **Be able to determine the cost of energy used in a system in order to be energy efficient**

Tariff structures: domestic; Domestic Economy 7; Domestic Smart 7; business (eg Economy 7 all-purpose, Economy 7 combined premises, evening and weekend); restricted hour; methods of controlling maximum demand; metering arrangements

Energy consumption: load scheduling; power factor correction techniques; calculation of apparent power rating of a capacitor to improve power factor of a load; location of power factor correction capacitors; efficient control of heating and lighting systems; recycling heat from heating and lighting systems

Cost of energy: cost of running a system using the different tariffs available; selection of appropriate tariff for a given installation and set of circumstances

5 **Understand the operation of a polyphase induction motor**

Types: single cage; double cage; wound rotor

Operating principles: production of a rotating magnetic field in the stator; synchronous speed; rotor resistance, reactance and induced voltage; standstill conditions; slip speed; the effect of rotor speed on rotor resistance and reactance; torque equations for a three-phase induction motor; torque/speed characteristic, stator and rotor losses; efficiency calculations

Starting methods: direct online; stator voltage reduction; rotor resistance method

Speed control: change of stator voltage and frequency

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Understand the operation of power transformers	1.1 explain the construction of different types of power transformer 1.2 identify the operating principles of a power transformer under no-load and load conditions 1.3 discuss the modes of connection for polyphase transformers
LO2 Understand the applications of circuit protection for distribution and installation systems	2.1 explain the construction of over-current protection devices 2.2 explain the operating principles of circuit over-current protection devices 2.3 explain the operating principles of earth fault protection devices
LO3 Understand the design and construction of lighting systems	3.1 explain the construction, operation and associated circuitry of common lamp types 3.2 explain the principles of good lighting design 3.3 plan a light scheme
LO4 Be able to determine the cost of energy used in a system in order to be energy efficient	4.1 discuss the factors governing tariff structures 4.2 analyse methods for reducing energy consumption 4.3 determine the cost of energy used in a system
LO5 Understand the operation of a polyphase induction motor	5.1 describe the types and explain the construction of induction motors 5.2 explain the operating principles and methods of starting induction motors 5.3 analyse the methods of speed control of induction motors.

Guidance

Links

This unit may be integrated with other units such as *Unit 1: Analytical Methods for Engineers*, *Unit 5: Electrical and Electronic Principles* and *Unit 63: Electrical Power*.

Essential requirements

Centres will need to provide access to appropriate laboratory test equipment (for example oscilloscopes, watt meters and test meters).

Single and three-phase supplies will also need be available, together with a variety of components including lamps (of various types), loads, transformers, induction motors, starters, etc.

Employer engagement and vocational contexts

Delivery of this unit will benefit from centres establishing strong links with employers willing to contribute to the delivery of teaching, work-based placements and/or detailed case study materials.

Unit 66: Electrical, Electronic and Digital Principles

Unit code: T/601/1395

Level: 5

Credit value: 15

Aim

This unit aims to develop learners' understanding of the electrical, electronic and digital principles needed for further study of electro-mechanical systems.

Unit abstract

This unit brings together the differing aspects of electrical, electronic and digital principles.

Learners will start by analysing series and parallel LCR circuits using complex notation and evaluating the effects on a circuit's performance by changes in impedance.

Learners will then use different circuit theorems to evaluate currents and voltages in electrical circuits. They will also consider the conditions for maximum power transfer and impedance watching.

The differing types and classes of operation of electronic amplifiers are analysed and evaluated before some are designed and tested then compared with theoretical results.

Finally, learners will investigate digital electronic device families and the design and testing of digital circuits.

Learning outcomes

On successful completion of this unit a learner will:

1 Be able to apply complex notation in the analysis of single phase circuits

2 Be able to apply circuit theory to the solution of circuit problems

3 Understand the operation of electronic amplifier circuits used in electro-mechanical systems

4 Be able to design and test digital electronic circuits used in electro-mechanical systems.

Unit content

1 **Be able to apply complex notation in the analysis of single phase circuits**

Series and parallel LCR circuits: voltage, current and power with sine wave signals; conditions for resonance eg frequency response, impedance, Q factor; complex notation

Circuit performance: tolerancing; effect of changes in component values

2 **Be able to apply circuit theory to the solution of circuit problems**

Circuit theorems: Norton; Kirchhoff; Thevenin; superposition; maximum power

Circuit analysis: mesh; nodal; maximum power transfer; impedance matching

3 **Understand the operation of electronic amplifier circuits used in electro-mechanical systems**

Single- and two-stage transistor amplifiers: class of operation eg A, B, AB and C; analysis of bias; DC conditions; AC conditions; coupling; input impedance; output impedance; frequency response

Design, test and evaluate: a single-stage amplifier to a given specification; compare measured and theoretical results

4 **Be able to design and test digital electronic circuits used in electro-mechanical systems**

Digital electronic devices: logic families eg TTL, LS-TTL and CMOS; comparison between families; circuits integration; identification of digital circuits in electro-mechanical systems

Combinational circuits: simplification methods; truth tables; single gate solutions; circuit simulation; testing

Design and test: circuit designed should be bread-boarded or simulated using an appropriate computer software package

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Be able to apply complex notation in the analysis of single phase circuits	1.1 solve problems involving LCR circuits 1.2 evaluate the effects on circuit performance of changes in values of impedances
LO2 Be able to apply circuit theory to the solution of circuit problems	2.1 solve problems using circuit theorems to calculate currents and voltage in circuits 2.2 analyse circuits including the value of circuit loads which produce maximum power
LO3 Understand the operation of electronic amplifier circuits used in electro-mechanical systems	3.1 analyse the operation of single- and two-stage amplifiers 3.2 evaluate the performance of single- and two-stage amplifiers 3.3 design and evaluate a single-stage transistor amplifier 3.4 compare measured results with theoretical calculations
LO4 Be able to design and test digital electronic circuits used in electro-mechanical systems	4.1 evaluate digital electronic device families 4.2 design combinational and sequential digital electronic circuits 4.3 test digital circuits by construction or by computer simulation.

Guidance

Links

This unit can be linked with *Unit 58: Microprocessor Systems.*

Essential requirements

Centres will need to provide access to appropriate laboratory test equipment, such as signal generators, oscilloscopes, power supplies and test meters, together with prototype boards and digital circuit trainers.

Appropriate software packages (for example circuit simulators such as PSpice, Tina Pro, or Electronics Workbench) will also need to be used to enable modelling and rapid prototyping, and to provide confirmation of experimental results.

Employer engagement and vocational contexts

Delivery would benefit from visits to local engineering companies that use a wide range of electro-mechanical systems. Delivery will also be helped by visits from guest speakers with relevant industrial experience.

Unit 67: Further Electrical Power

Unit code: K/601/1393

Level: 5

Credit value: 15

Aim

The aim of this unit is to extend learners' understanding of the distribution of electrical power and help them to meet the energy deployment needs of the future.

Unit abstract

Energy, either from traditional fossil fuels or sustainable alternative energy sources, needs to be converted into an appropriate format to allow for efficient reliable transmission and distribution to the various users, at acceptable quantities, to meet their requirements.

The dissemination of electrical energy is a problem of ever-growing complexity as our dependency grows on its use and consistency of availability. Our communications, transport and commercial operational systems, to name but a few, would all come to an abrupt halt, should it fail to deliver. Historically, 'heavy current' engineers have focused broadly on thermal/current, voltage and system operation constraints. Now with environmental concerns increasing, aesthetic issues, maximising use of existing systems through upgrades, preventive and fault management and reduction of energy loss throughout the transmission and distribution system all need to be taken into account.

This unit develops an understanding of transmission and distribution topics and focuses on the use of overhead lines and cables within power systems. The origin and propagation of surges and transients are analysed. The subject matter of power system faults is, for simplicity, limited to analysing symmetrical faults and logically relates to aspects of power system protection schemes. The synchronisation, operation and use of synchronous machines are also investigated.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand the construction and properties of overhead lines and cables

2 Understand symmetrical faults and protection schemes

3 Be able to analyse power system transients

4 Understand the synchronising and control of synchronous machines.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017

Unit content

1 **Understand the construction and properties of overhead lines and cables**

Construction and properties: tower; post; ASCR conductor; disc and pin insulators; string efficiency; grading rings; arcing horns; corona; bundled conductors; dampers; transposition; span and sag

Cable types: construction of single core and three core cables; properties eg capacitance, dielectric, voltage rating, electric stress, thermal resistance, losses, heating and cooling, belted type, screens, superconducting cables; comparison of different types used in power systems

Fault location: description of methods used in cables and lines eg resistance bridges, time domain reflectometry, tracing methods, energy discharge, thermal imaging

Performance evaluation: short and medium length eg series impedance, 'T' and 'π' models, voltage drop, current drop, power losses, Ferranti effect

2 **Understand symmetrical faults and protection schemes**

Components: current transformers eg burden, open circuit operation; over-current relays eg induction disc, thermal, solid state; Buchholz relay; circuit breakers eg air blast, oil, vacuum; fuses

Fault analysis: symmetrical faults in three phase systems eg fault limiting reactors, ring and tie bar reactors, per unit values, fault level, fault current, simulation of faults

Protection schemes: type eg unit protection, time graded over-current, distance protection, transformer protection, feeder protection, motor protection; properties eg co-ordination, discrimination; testing eg CT polarity, CT knee-voltage, CT magnetising characteristic, commissioning, primary and secondary injection

3 **Be able to analyse power system transients**

Surges: origin eg lightning and switching operations; propagation and effects of surges eg surge impedance, surge velocity, basic impulse level (BIL); voltage and current surges; reflection coefficient; propagation and reflection of surges at junctions of lines and cables; use of Bewley lattice diagram to analyse multiple reflections; circuit breaker transients

Surge control: description of methods and components eg surge diverter, rod gap, expulsion tube

4 **Understand the synchronising and control of synchronous machines**

Synchronising: requirements on the 'running and incoming' voltages eg magnitude, frequency, phase, phase sequence; synchronising methods eg three lamp methods, synchroscope

Control of synchronous machines: methods of operational control eg voltage, frequency, power, power factor, infinite bus-bars, V-curves

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Understand the construction and properties of overhead lines and cables	1.1 explain the construction and properties of an overhead line 1.2 compare different types of cable used in power systems 1.3 explain methods of fault location 1.4 use T and π models to evaluate performance
LO2 Understand symmetrical faults and protection schemes	2.1 explain the function of the components in a protection scheme 2.2 use one-line diagrams to solve fault analysis problems 2.3 solve problems involving the use of fault-limiting reactors 2.4 analyse the protection scheme used in a given system
LO3 Be able to analyse power system transients	3.1 analyse the propagation of surges 3.2 use a Bewley lattice diagram to analyse multiple reflections 3.3 explain how surges occur and compare two methods used for surge control
LO4 Understand the synchronising and control of synchronous machines	4.1 analyse and compare two methods of synchronising 4.2 explain how the control of voltage, frequency and power factor of a synchronous machine can be achieved.

Guidance

Links

This unit may be linked with *Unit 1: Analytical Methods for Engineers*, *Unit 5: Electrical and Electronic Principles* and *Unit 63: Electrical Power*.

Essential requirements

Sufficient laboratory and test equipment will need to be available to support a range of practical investigations (eg protection relays, current transformers, synchronous machine, synchroscope, etc).

Employer engagement and vocational contexts

Delivery of this unit will benefit from centres establishing strong links with employers willing to contribute to the delivery of teaching, work-based placements and/or detailed case study materials.

Unit 68: Applications of Power Electronics

Unit code:	D/601/1391
Level:	4
Credit value:	15

Aim

This unit will develop a technical understanding of power electronics and their application to variable speed drives.

Unit abstract

Power electronics involves the use of semiconductor devices to control a range of applications in rectification, DC and AC motor control and controlled power supplies. To meet the challenges expected of a modern 'heavy current' engineer the unit carries an emphasis on the application of power electronics to variable speed controllers. The focus is on the power aspects rather than the associated detail of the electronic control and firing circuitry.

In every aspect of engineering variability exists and therefore acceptable tolerances are specified to define close limits of output. Testing and measurement must make use of safe techniques and in this case are conducted via the use of isolating probes and transducers in systems operating from earthed power systems.

The unit involves practical investigations of common configurations of controlled rectifier and inverter systems, as applied to alternating and direct current motor control. The use of commercial/industrial variable speed drives provides a relevant and convenient method of investigation. To broaden the scope of the subject, non-drive applications of power electronics are investigated and developed to meet local industrial requirements.

No matter in which sector he/she is involved, the modern engineer needs to be energy conscious and therefore must seek and implement ways of conserving valuable resources.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand common configurations for controlled and uncontrolled rectification

2 Understand the methods used for AC motor control

3 Understand the methods used for DC motor control

4 Understand other applications of power electronics.

Unit content

1 **Understand common configurations for controlled and uncontrolled rectification**

Standard configurations: half wave and full wave bridge circuits; resistive and inductive loads, flywheel diodes

Signal parameters: amplitude; peak-to-peak; waveforms; full and half wave forms; ripple; average and root-mean-square (RMS) values; pulse number; harmonics; resonance calculations of signal parameters of rectified waveforms eg average and root-mean-square (RMS) values, pulse number, waveforms, harmonics

Device protection: protection methods for power semiconductors eg over-voltage, over-current, transients

Measurement techniques: safety considerations in a heavy current power environment eg in systems where voltages exceed 50V; use of isolated differential voltage attenuator probes; Hall effect current probes; power oscilloscope

2 **Understand the methods used for AC motor control**

Frequency conversion methods: inverter switching strategies eg quasi-square-wave, pulse width modulation, cycloconverter, waveforms, harmonics, filters

AC motor control: soft starter; speed; torque; reversal; braking; voltage; frequency; voltage/frequency (V/Hz); vector control

Investigation of an industrial AC motor controller: preparation and interpretation of circuit and block diagrams; setting of parameters eg min/max speed, ramp up/down time, current/torque limits; applications eg process control, mills, fans, conveyor systems; specification and selection

3 **Understand the methods used for DC motor control**

Speed control of DC motor: armature voltage; field weakening; DC choppers; controlled rectifiers; closed loop; tacho-generator; reversal; braking; waveforms

Torque control of DC motor: armature current control loops; speed reversal; braking; single quadrant; four quadrant operation; regeneration

Investigation of an industrial DC motor controller: preparation and interpretation of circuit and block diagrams; setting of parameters eg min/max speed, ramp up/down time, current/torque limits; applications eg process control, mills, pumps, CNC machinery; specification and selection

4 **Understand other applications of power electronics**

Principles: comparison of the principles of operation; control techniques; protection methods; use of block and circuit diagrams

Other applications: applications eg uninterruptible power supplies, high voltage DC links, inductive heating, welding machines, compact fluorescent lighting

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Understand common configurations for controlled and uncontrolled rectification	1.1 compare standard configurations used in single and three-phase systems 1.2 calculate signal parameters of a rectified waveform 1.3 explain methods of device protection 1.4 use safe measurement techniques when measuring current and voltage in earthed systems
LO2 Understand the methods used for AC motor control	2.1 explain methods of frequency conversion 2.2 explain methods of control for an AC motor 2.3 investigate an industrial AC motor controller
LO3 Understand the methods used for DC motor control	3.1 explain methods of speed control for a DC motor 3.2 explain methods of torque control for a DC motor 3.3 examine an industrial DC motor controller
LO4 Understand other applications of power electronics	4.1 compare the principles of three other applications of power electronics 4.2 investigate an area of application for each of the three applications.

Guidance

Links

This unit may be linked with *Unit 1: Analytical Methods for Engineers*, *Unit 5: Electrical and Electronic Principles*, *Unit 63: Electrical Power* and *Unit 67: Further Electrical Power*.

Essential requirements

Centres will need to provide access to sufficient laboratory and test equipment to support a range of practical investigations (eg differential isolated voltage probes, Hall effect current probes, power analyser, DC and AC motors, industrial motor controllers, etc).

Employer engagement and vocational contexts

The delivery of this unit will benefit from centres establishing strong links with employers willing to contribute to the delivery of teaching, work-based placements and/or detailed case study materials.

Unit 69: Advanced Computer-aided Design Techniques

Unit code:	Y/601/1390
Level:	4
Credit value:	15

Aim

The aim of this unit is to enhance learners' skills in the use of computer-aided design (CAD) and 3D modelling systems to solve a design problem.

Unit abstract

Product designers communicate their designs through CAD software packages. It is used at all stages of the design task, from conceptualisation to production of working drawings. It provides the basis for manufacturing products. Engineers must master computer-aided design techniques in order to ensure design intent is accurately taken through to manufacture and service. In this unit the learner will practice the techniques involved in producing advanced 3D models. Simple errors with CAD models and drawings can lead to hugely expensive consequences. This could be in the form of incorrect tooling or products which do not fit or function properly. In industry, competitive advantage is gained through speed to market of new designs. Hence engineers must be able to commit their designs quickly to CAD.

This unit will be beneficial to research and design engineers and production engineers. It will equip the learner with the necessary advanced CAD parametric modelling skills that industry demands. Learners should be able to produce and edit 2D shapes prior to starting this unit. Learners will investigate a CAD software package so as to be able to generate advanced surface and solid models. There are a variety of CAD software packages used in industry today including Pro-Engineer and Solidworks. Whilst there may be differences in using the different softwares, users who are fluent in one software will generally quickly pick up any other.

Entry requirements for this unit are at the discretion of the centre. However, it is advised that learners should have completed appropriate BTEC National units or equivalent. Learners should be able to produce and edit 2D shapes prior to starting this unit. Those who have not attained this standard will require bridging studies.

Learning outcomes

On successful completion of this unit a learner will:

1 Be able to modify and update an existing design

2 Be able to generate a surface model

3 Be able to generate a solid model.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017 © Pearson Education Limited 2017

Unit content

1 **Be able to modify and update an existing design**

Drawing files: load and create and edit a drawing file from source, including Initial Graphics Exchange Specification **(**IGES) and Drawing Exchange Format (DXF) files

Blocks: access externally and internally referenced blocks; update and insert new blocks; use editing commands to modify existing parts

Record modifications: update the drawing and record modifications; produce updated documentation using a word-processing package with inserted views relating to modifications

Produce hard copy: produce hard copy of updated drawing using scaled plots, scaled views, different printer/plotters and reconfiguring CAD software to suit

2 **Be able to generate a surface model**

Coordinate systems: manipulate user co-ordinate system (UCS) and world coordinate system (WCS) to suit required geometry

Correct geometry: using polylines to construct shapes for surfacing and constructing splines; using polyedit to restructure line/arcs into continuous geometry

Surface construction: generate the bounded geometry required for any surface; use generated geometry to create surfaces; use of all methods of surface construction with reference to Bezier, Nurbs, Patch and Coons, to test best construction methods

Facet numbers: numbers required to smooth surface; memory problems using high numbers of facets

Viewing medium: use of Hide, Shade and Render to visualise the product; print or plot finish drawing; the use of different textures; lighting controls

3 **Be able to generate a solid model**

Coordinate systems: manipulate UCS and WCS to suit required geometry

Solid model: using polylines to construct shapes for extruding, using polyedit to restructure line/arcs into continuous geometry; use of Hide, Shade and Render to visualise the product; applying various materials to generated slides; cutting the solids and sectioning; different lighting; textures

Construction techniques: the effects of subtract, union, intersect extrude, sweep and revolve in model construction; editing the geometry using fillet, chamfer etc; using primitives to create geometry

Properties of solids: using solid model to find the mass, radius of gyration, centre of gravity and surface area

Printing image: generating image

Dimension a solid: dimensions are correctly added to a solid composite drawing in multi-screen mode; dimensions are correctly added to true shapes previously extracted from solid composite

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Be able to modify and update an existing design	1.1 load drawing files from varying sources using different formats 1.2 update the modified blocks and load into drawing 1.3 modify drawing to new requirements and record modifications 1.4 create a word-processed report with modified parts of drawing inserted 1.5 produce and print/plot report and drawing
LO2 Be able to generate a surface model	2.1 manipulate the user coordinate system (UCS) and world co-ordinate system (WCS) to suit construction requirements 2.2 produce shapes that contain the correct geometry for the required surface 2.3 create the correct surface construction 2.4 produce a surface that is compatible with processing limits 2.5 create a suitable viewing medium 2.6 produce a report describing the different methods of constructing a surface
LO3 Be able to generate a solid model	3.1 manipulate the user coordinate system (UCS) and world coordinate system (WCS) to suit construction requirements 3.2 create bounded geometry for extrusion and revolving 3.3 produce sections from solid model 3.4 demonstrate the use of construction techniques 3.5 produce file containing mass, surface area, radius of gyration and centre of gravity 3.6 produce a report detailing the uses of solid modelling in the manufacturing process.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017 © Pearson Education Limited 2017

Guidance

Links

This unit is designed to stand alone, but it has links with *Unit 8: Engineering Design*, *Unit 14: Computer-aided Machining* and *Unit 15: Design for Manufacture*.

Essential requirements

Centres delivering this unit must be equipped with an industrial-standard CAD package and with printing or plotting facilities for rendered images, for example software Pro-Engineer, Solidworks, AutoCAD, RoboCAD, TurboCAD, and Intergraph.

Employer engagement and vocational contexts

Centres should try to work closely with industrial organisations in order to bring realism and relevance to the unit.

Visits to one or two relevant industrial or commercial organisations that use advanced CAD techniques will be of value to enhance and support learning.

Unit 71: Combinational and Sequential Logic

Unit code:	K/601/1362
Level:	4
Credit value:	15

Aim

This unit aims to provide learners with the skills and understanding required to design and build electronic circuits that use combinational and sequential logic.

Unit abstract

This unit will develop learners' understanding of digital techniques and the practical applications of both combinational and sequential logic.

Learners will investigate the characteristics and applications of combinational and sequential logic devices. They will then design, construct and test combinational and sequential circuits and will use relevant computer software to simulate and verify circuits.

Learners will then go on to design a digital system that meets a specification and will evaluate the design against given criteria. They will investigate the minimisation of digital circuits and will improve the digital system design through the use of programmable logic devices (PLDs).

Learning outcomes

On successful completion of this unit a learner will:

1 Be able to design and build circuits using combinational logic

2 Be able to design and build circuits using sequential logic

3 Be able to design and evaluate a digital system.

Unit content

1 **Be able to design and build circuits using combinational logic**

Manufacturers' data sheets: printed; CD ROM; websites

Devices: buffer; line driver; decoder; multiplexer; programmable read-only memory (PROM); programmable logic devices

Characteristics: device technology eg transistor-transistor logic (TTL), complementary metal-oxide–semiconductor (CMOS); function; fan-out; propagation delay; power consumption; cost; size; packaging; operating voltage; availability

Computer simulations: using a commercial digital electronic circuit analysis package

2 **Be able to design and build circuits using sequential logic**

Sequential logic devices: J-K flip-flop; D-type flip-flop; monostable; counter; parallel latch; shift register

Design sequential circuits: minimisation; race hazards; clock speeds; power supply decoupling; clock speed/power trade-off for CMOS

Sequential logic circuits: clock generator; BCD counter; parallel to serial converter; pseudo random number generator

Computer simulation: using a commercial digital electronic circuit analysis package

3 **Be able to design and evaluate a digital system**

Digital system design: systems with both combinational and sequential devices; up to 20 components; possibly including programmable devices

Evaluation criteria: functionality; chip count; cost

Reduce chip count: by replacing logic devices with programmable devices eg erasable programmable logic devices (EPLD), Generic Array Logic (GAL) devices, Programmable Array Logic (PAL) devices, programmable read-only memory (PROM)

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Be able to design and build circuits using combinational logic	1.1 interpret manufacturers' data sheets to select appropriate combinational logic devices for specific purposes 1.2 compare the characteristics of similar devices using different technologies 1.3 design, construct and test combinational circuits 1.4 use computer software packages to simulate logic circuits
LO2 Be able to design and build circuits using sequential logic	2.1 describe the operation of sequential logic devices 2.2 use formal design techniques to design sequential circuits 2.3 construct and test sequential circuits 2.4 use computer simulation to verify logic designs
LO3 Be able to design and evaluate a digital system	3.1 design a digital system to meet a technical specification 3.2 realise, test and evaluate the design against criteria 3.3 improve the design by reducing the chip count through the use of programmable logic devices.

Guidance

Links

This unit may be linked with *Unit 66: Electrical, Electronic and Digital Principles*.

Essential requirements

Centres need to provide access to manufacturers' data sheets and computer circuit analysis packages for circuit simulation.

Employer engagement and vocational contexts

Delivery would benefit from visits to local engineering companies that build a wide range of digital systems and from visits from guest speakers with relevant industrial experience.

Unit 73: Principles of Electronic Product Manufacture

Unit code: A/601/1382

Level: 5

Credit value: 15

Aim

This unit will develop learners' understanding of the principles and techniques used in the production of modern electronic products.

Unit abstract

This unit introduces learners to the principles and current practices used in the production of a wide variety of electronic products.

Techniques used in the fabrication of microelectronic devices are discussed, as are techniques used for the assembly of printed circuit boards (PCB), both single and double-sided, and multi-layer types. Conventional through-hole and surface mounted manufacturing techniques are considered, together with the use of robots for components placement including selection criteria and associated costs.

The design and fabrication of sheet metal and non-metal enclosures for electronic products is covered and associated assembly processes are also discussed.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand the production and packaging of solid-state electronic devices

2 Understand electronic component design parameters

3 Understand the methods used for the design, simulation, manufacture and testing of printed circuit boards (PCB)

4 Understand the key elements of an automated PCB assembly facility.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017 © Pearson Education Limited 2017

Unit content

1 **Understand the production and packaging of solid-state electronic devices**

Production of solid-state electronic devices: semiconductors; silicon; wafer preparation; crystal growing; design and production of components eg transistors, diodes, capacitors, resistors; integrated circuits; film deposition; oxidation; lithographic techniques; etching; diffusion; ion implantation; metallisation; bonding and packaging

Device packaging: comparison of leaded and surface mount devices, physical characteristics, production requirements, applications, motivators, economics of production and market requirements

2 **Understand electronic component design parameters**

Design rules: smallest obtainable transistor size – gains and losses; wet and dry etching – minimum photoresist width, selectivity of etchants; effects of altering polysilicon gate width on transistor speed

Failure modes: relationship with chip size; testing and prediction of failure modes – statistical methods, failure mechanisms; wafer manufacture – effects of changes in chip size, wafer size, process complexity

3 **Understand the methods used for the design, simulation, manufacture and testing of printed circuit boards (PCB)**

PCB design and simulation: electromagnetic compatibility (EMC); special requirements of radio frequency (RF) circuits; benefits of surface mount technology; circuit board layout – electronic computer-aided design (ECAD); simulation of circuit operation; design for test; link to computer numerical control (CNC) eg drilling and routing machines

PCB manufacture: print and etch; drilling; routing; deburring; wave and flow soldering; conductive adhesion; fluxes and cleaning; component solder-ability; thermal stresses; safety considerations; inspection methods and equipment; reworking of PCBs

Electronic enclosures: metal and non-metal enclosures, fabrication and assembly of enclosures, screening and electromagnetic compatibility (EMC)

Testing of PCBs and finished products: 'burn-in' and accelerated life tests; automatic test equipment (ATE); boundary scanning; mean time to failure (MTTF)

4 **Understand the key elements of an automated PCB assembly facility**

Automated PCB assembly: component supply, packaging and form of supply; component orientation and polarisation; suitability for automated assembly; static sensitivity; automated component placement

Use of robots: robotic assembly; selection criteria for assembly machines and systems eg sequential, simultaneous, test during placement, assembly performance and cost, accuracy and reliability, re-tooling time and cost of tooling; adhesive dispensing; safe use of adhesives; programming of machines

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Understand the production and packaging of solid-state electronic devices	1.1 describe the production of solid-state devices common to the electronics industry 1.2 evaluate the different types of device packaging available
LO2 Understand electronic component design parameters	2.1 explain the effects of altering given design rules on microelectronic devices 2.2 explain failure modes and mechanisms for a range of microelectronic devices
LO3 Understand the methods used for the design, simulation, manufacture and testing of printed circuit boards (PCB)	3.1 explain the design and simulation of single- and multi-layer PCBs 3.2 specify the types of equipment required for automated PCB manufacture and assembly 3.3 explain the methods of testing completed PCBs and finished electronic products 3.4 explain the methods of designing and producing casings and housings for electronic products
LO4 Understand the key elements of an automated PCB assembly facility	4.1 describe the key elements of an automated PCB assembly facility 4.2 evaluate the use of robots for components placement including selection criteria and associated costs.

Guidance

Links

This unit can be linked to *Unit 39: Electronic Principles*.

Essential requirements

Learners will need to have access to appropriate PCB design and production equipment.

Employer engagement and vocational contexts

Delivery would benefit from visits to local electronic manufacturing companies and from visits from guest speakers with relevant industrial experience.

Unit 74: Vehicle Fault Diagnosis

Unit code: H/601/1375

Level: 4

Credit value: 15

Aim

This unit will develop learners' understanding of vehicle fault diagnosis and will give them the practical skills needed to diagnose vehicle faults and assess serviceability.

Unit abstract

This unit will provide learners with an advanced understanding of vehicle fault diagnosis and will enhance their ability to diagnose faults and select appropriate equipment from given data in a number of disciplines. They will also learn about techniques of measurement when determining the performance of a vehicle system.

Learning outcome 1 will enable learners to increase their knowledge of fault diagnostic techniques and the interpretation of fault symptoms. Learning outcome 2 considers the principles of measurement and testing to determine the performance of vehicle systems. Learning outcome 3 is concerned with the evaluation and presentation of test results and the production of a fault location guide for a given vehicle.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand vehicle systems fault diagnosis criteria and techniques

2 Be able to use fault diagnostic techniques and equipment to determine the performance of vehicle systems

3 Be able to evaluate and present findings of a vehicle fault diagnostic test and produce a fault location guide.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017 © Pearson Education Limited 2017

Unit content

1 **Understand vehicle systems fault diagnosis criteria and techniques**

Diagnosis specifications: prioritised list of technical and non-technical requirements for carrying out fault diagnosis; symptoms; repair recommendations eg for mechanical, electrical, electronic or computer-based vehicle systems

Diagnostic techniques: eg symptom-fault-cause-location diagnostic sequence, historical knowledge of system faults, application of problem solving techniques

Factors: factors that contribute to diagnosis eg logical process, diagnostic and specialist equipment required, on-board computer-based and telemetry diagnostic systems, equipment costs, likely time saving, ability to upgrade, ease of use, manufacturers' back-up, workshop manuals, technical (phone/fax/email/internet, technical bulletins)

2 **Be able to use fault diagnostic techniques and equipment to determine the performance of vehicle systems**

Test equipment: equipment eg cylinder leakage tester, exhaust gas analyser, electronic meter, fuel pressure gauge, engine analyser, computer based and telemetric devices

Fault diagnosis: diagnosis on the agreed vehicle systems; diagnostic aids

Symptoms: fault symptoms eg loss of power, high fuel consumption, poor acceleration

Repair recommendations: type of repair eg adjustment, replacement, repair; justification of solution(s) eg based on cost, serviceability, reliability, safety

3 **Be able to evaluate and present findings of a vehicle fault diagnostic test and produce a fault location guide**

Technical report: word-processed technical report including nature and setting of the fault eg vehicle, symptoms, setting (road side or workshop), suspected system or systems, description of techniques and equipment used, test results, interpretation of results, conclusions and known data for that system, references used

Present findings: presentation eg to peers and/or supervisor/tutor; use of suitable visual aids eg sketches, graphs, charts, drawings, spreadsheets; use of presentation packages where appropriate

Fault location guide: prepared for a given vehicle system and including expected test readings, description of the system with an explanation of its use, theory of operation, instruments and special tools required, test instructions, step-by-step fault location guide to fault diagnostic procedure

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Understand vehicle systems fault diagnosis criteria and techniques	1.1 identify and justify a diagnosis specification for a mechanical or an electrical or an electronic vehicle system 1.2 use, explain and record the results of at least two suitable vehicle systems diagnostic techniques 1.3 compare the factors that contribute to quick and effective diagnosis of a given vehicle system
LO2 Be able to use fault diagnostic techniques and equipment to determine the performance of vehicle systems	2.1 select and use appropriate test equipment 2.2 carry out a systematic fault diagnosis 2.3 interpret faults from given symptoms and justify repair recommendations
LO3 Be able to evaluate and present findings of a vehicle fault diagnostic test and produce a fault location guide	3.1 produce a written report of the test results 3.2 interpret and justify the test results in terms of the known data for that system 3.3 create an effective fault location guide for a mechanical or an electrical or an electronic system.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017

Guidance

Links

This unit has links with *Unit 25: Engine and Vehicle Design and Performance*, *Unit 75: Vehicle Systems and Technology* and *Unit 79: Vehicle Electronics*.

Essential requirements

A number of suitable diagnostic aids are essential for the delivery of this unit including a compression tester, cylinder leakage tester, engine analyser and multimeters. Access to manufacturers' manuals and vehicle data is also required.

Employer engagement and vocational contexts

Delivery of this unit would benefit from guest speakers from industry and visits to motor industry test facilities.

Unit 75: Vehicle Systems and Technology

Unit code: D/601/1374

Level: 5

Credit value: 15

Aim

This unit will develop learners' understanding of the operating principles associated with advanced vehicle systems and will give them the skills needed to carry out diagnostic procedures on these systems.

Unit abstract

This unit will develop learners' knowledge of electronic power steering systems and active suspension control systems. Learners are then introduced to anti-locking braking systems, traction control systems and integrated dynamic stability control systems.

Learning outcome 3 is concerned with advanced central locking and security systems, integrated heating and air conditioning and driver and passenger impact protection. Finally learners will carry out and record the results of practical fault diagnosis tests on advanced vehicle power steering, suspension and central body systems. This will also require them to interpret the results from the fault diagnosis tests and evaluate the serviceability of a system and its components.

Learning outcomes

On successful completion of this unit a learner will:

1. Understand vehicle electronic power steering and active suspension systems
2. Understand vehicle anti-lock braking, traction control and integrated dynamic stability control systems
3. Understand vehicle security, environmental control and passenger protection systems
4. Be able to carry out diagnostic procedures on power steering, suspension and central body systems.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017

Unit content

1 **Understand vehicle electronic power steering and active suspension systems**

Advanced power steering: components of integral power steering with electronic control; principles of operation; electrical and hydraulic circuit diagrams; control systems; service and repair procedures and safety aspects; system operation under various conditions eg parking, negotiating bends

Active suspension and ride control: components of active vehicle chassis management system including self-levelling suspension, ride control, electronic damper control and active rear suspension/axle control; electrical and hydraulic circuit diagrams; system operation under various conditions eg cruise, acceleration, braking, cornering

Service and repair procedures: manufacturers' recommendations for service and repair; safety aspects to be considered; specialist equipment and tools required; correct test conditions; inter-relationships of systems

2 **Understand vehicle anti-lock braking, traction control and integrated dynamic stability control systems**

Anti-lock braking (ABS): principles of operation and components of an anti-lock braking system eg electrical and hydraulic circuits, system operation under various conditions such as emergency braking, ice

Traction control – Anti Slip Regulations (ASR): principles of operation and components of a traction control system eg electrical and hydraulic circuits; system operation during acceleration, cornering and braking

Service and repair procedures: manufacturers' recommendations for service and repair; safety aspects to be considered; specialist equipment and tools required; correct test conditions; inter-relationships of systems

Integrated dynamic stability control: functional description of system to include operational criteria eg under-steer, lateral acceleration, vehicle rotation speed, steering angle and wheel speeds; corrective strategies eg braking control and engine power regulation; sensing components and electrical/hydraulic circuits

3 **Understand vehicle security, environmental control and passenger protection systems**

Central locking and security: components of microprocessor-controlled central locking and thief proofing system; operating principles including infrared control, Doppler movement sensing, crash sensing, failsafe and safety features; system operation under various conditions eg attempted break-in, accident; developments in vehicle security systems

Environmental control: components of integral heating and air conditioning system; operating principles; sensing and control functions; system operation under various conditions; developments in vehicle environmental control systems

Passenger protection: components of air bag systems eg front and side impact systems; operating principles; operation of system during frontal and side impact; passenger restraints eg seat belt tensioners and head restraint; developments in driver and passenger impact protection

Service and repair procedures: manufacturers' recommendations for service and repair; safety aspects to be considered; specialist equipment and tools required; correct test conditions

4 **Be able to carry out diagnostic procedures on power steering, suspension and central body systems**

Fault diagnostic tests: testing eg visual inspection, functional tests and system condition monitoring systems, electrical tests using multi-meters, oscilloscopes and dedicated test equipment on sensors, actuators and control units associated with the above systems, pressure tests on hydraulic systems

Present results: written, verbal and visual techniques

Serviceability: make recommendations for component repair/replacement and serviceability

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Understand vehicle electronic power steering and active suspension systems	1.1 explain the principles of operation and identify major components of an advanced power steering system 1.2 explain the principles of operation and identify major components of an active suspension and ride control system 1.3 explain service and repair procedures for an advanced power steering system and an active suspension and ride control system
LO2 Understand vehicle anti-lock braking, traction control and integrated dynamic stability control systems	2.1 explain the principles of operation and identify major components of an anti-lock braking system 2.2 explain the principles of operation and identify major components of a traction control system 2.3 examine the service and repair procedures for an anti-lock braking system and a traction control system 2.4 examine the function of an integrated stability control system
LO3 Understand vehicle security, environmental control and passenger protection systems	3.1 explain the operating principles and identify major components of an advanced central locking and security system 3.2 explain the operating principles and identify major components of an environmental control system 3.3 examine the operation of a passenger protection system 3.3 explain the service and repair procedures of an advanced central locking and security system 3.4 explain the service and repair procedures of an environmental control system
LO4 Be able to carry out diagnostic procedures on power steering, suspension and central body systems	4.1 carry out fault diagnosis tests on advanced vehicle power steering, suspension and central body systems and record the results 4.2 interpret and present results from a fault diagnosis test 4.3 report on the serviceability of a system and the major components in that system.

Guidance

Links

This unit has links with *Unit 79: Vehicle Electronics* and *Unit 74: Vehicle Fault Diagnosis*. If evidence relates to more than one unit care must be taken to ensure it is tracked so it is clear which unit it relates to.

Essential requirements

Learners will need access to a range of stand-alone vehicle systems, simulators and equipment to support practical investigations and testing. Access to manufacturers' manuals is also required.

Employer engagement and vocational contexts

The unit would benefit from an input by guest speakers from industry and visits to motor industry test facilities.

Unit 76: Managing the Work of Individuals and Teams

Unit code: R/601/0304

Level: 5

Credit value: 15

Aim

This unit develops learners' understanding and skills associated with managing the work of individuals and teams. It enhances the ability to motivate individuals and to maximise the contribution of teams to achieve outcomes.

Unit abstract

All scientific tasks are carried out by personnel working either as an individual or as a member of a team. The role of an individual can be defined by a job description that states responsibilities, objectives and performance targets.

At one or more stages during the execution of a task it is common to assess performance through an appraisal system designed to evaluate progress, motivate future performance and set new targets. A similar procedure would apply to teamwork and team performance.

In this unit learners will develop the skills associated with setting job descriptions and targets for individuals and teams and then review their performance.

Learning outcomes

On successful completion of this unit a learner will:

1 Be able to establish the objectives of individuals

2 Be able to evaluate the performance of individuals

3 Be able to establish the roles and responsibilities of teams

4 Be able to review the performance of teams.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017 © Pearson Education Limited 2017

Unit content

1 **Be able to establish the objectives of individuals**

Job description: analysis of jobs; behaviour; responsibilities and tasks; pay; bonus; incentives

Employee: any person working in the applied science sector with responsibility to a line manager

Roles: any specific activity or group of activities within the applied science sector

Responsibilities: direct and indirect relationships; relations between personal and team responsibility

Performance targets: personal; financial; quantity and quality; incorporation within a job description; setting and monitoring performance targets

2 **Be able to evaluate the performance of individuals**

Employee appraisal system: reasons for using performance appraisals eg to determine salary levels and bonus payments, promotion, establish strengths and areas for improvement, training needs, communication; establishing appraisal criteria eg production data, personnel data, judgemental data; rating methods eg ranking, paired comparison, checklist, management by objectives

Staff appraisal schedule: conduct of performance reviews eg by supervisor, peers, committee, subordinates or self-appraisal

Feedback of results: comments on positive and negative aspects of performance related to targets, conduct and timekeeping; resolution of conflicts

Encouragement: as a motivator for the achievement of performance targets eg strengths, rewards

3 **Be able to establish the roles and responsibilities of teams**

Teams: management teams and peer groups eg focus groups, task groups, project groups, panels; purpose of teams eg long and short term, specific project or task, seeking views within the company and from external sources, communication

Team responsibilities: to superiors; subordinates; the business; each other and external groups eg meeting performance targets, communicating results, confidentiality, deadlines

Targets: realistic deadlines; new and or amended outcomes

Internal team management: hierarchical; functional

4 **Be able to review the performance of teams**

Team performance: appraisal systems; reasons for appraising team performance eg team effectiveness, contribution to business, constitution of team, identifying individual contributions to the team effort and determining the need to establish other team criteria

Performance criteria: formulate appropriate criteria eg outcome data, achieved improvements, employee morale, value added

Performance review: conduct a team performance review eg as individual manager, outside person; team self-appraisal; feedback of results and resolution of conflicts within the team

Team motivation: encouragement of overall team performance as a motivator for the achievement of objectives

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Be able to establish the objectives of individuals	1.1 identify the essential elements of a job description 1.2 design a job description for an employee 1.3 produce a schedule of the roles and responsibilities of individuals 1.4 agree performance targets for an individual
LO2 Be able to evaluate the performance of individuals	2.1 explore the key factors in establishing an employee appraisal system 2.2 develop a staff appraisal schedule for use by a manager 2.3 provide feedback to an individual who has undergone an appraisal 2.4 encourage an individual to achieve performance targets
LO3 Be able to establish the roles and responsibilities of teams	3.1 identify teams suitable for a variety of purposes 3.2 determine the responsibilities of teams to different personnel within an organisation 3.3 set suitable targets for teams 3.4 compare various types of internal team management
LO4 Be able to review the performance of teams	4.1 identify the reasons for appraising team performance 4.2 formulate the criteria by which the performance of different types of teams can be measured 4.3 conduct a performance review of a team 4.4 produce a report on the factors that are likely to motivate a team to achieve its defined objectives.

Guidance

Links

This unit can be linked with *Unit 38: Managing People in Engineering*.

Essential requirements

There are no essential requirements for this unit.

Employer engagement and vocational contexts

Wherever possible, learners should base their examples on specific tasks and teamwork within local applied science-related industries. They should study the structure and activities of the company and, where possible, visit the company to witness practices and procedures relating to individual and group work, target setting and evaluation.

Unit 77: Plan and Co-ordinate Vehicle Maintenance

Unit code: L/601/1371

Level: 5

Credit value: 15

Aim

This unit aims to develop learners' knowledge and understanding of the planning, coordination and control of vehicle fleet maintenance.

Unit abstract

This unit introduces the learner to the various types of maintenance contracts used and the management practices necessary to ensure that vehicles are maintained safely, economically and that legal obligations are complied with.

Learners will be given the opportunity to study various fleet management systems used to plan and control vehicle maintenance. They will develop the ability to select or design an appropriate fleet maintenance system.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand the legal and operational implications of a vehicle maintenance contract

2 Understand fleet maintenance management systems

3 Understand the legal implications relating to vehicle maintenance

4 Understand how to control the maintenance of a vehicle fleet.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017 © Pearson Education Limited 2017

Unit content

1 **Understand the legal and operational implications of a vehicle maintenance contract**

Types of vehicle maintenance contract: eg contract hire, lease hire, rental, manufacturer contract, power by the hour, fleet maintenance

Legal and operational implications: contract law; supply of services; construction and use regulations; transport act; plating and testing; environmental legislation

Vehicle maintenance contracts: controls; staffing; records; financial considerations; company taxation; operational factors; operator licensing

2 **Understand fleet maintenance management systems**

Management systems selection criteria: eg based on fleet size, fleet type, type of operation, cost, time, location

Management systems: mileage; time; scheduled; unscheduled; corrective; emergency

Customer requirements: eg frequency, reporting requirements, documentation, emergency situations, overnight servicing/repairs, vehicle inspections

3 **Understand the legal implications relating to vehicle maintenance**

Legal requirements: eg operator's licence, construction and use regulations, plating and testing, MOT testing, environmental considerations

Implications and processes: responsibilities; staff qualifications; facilities; equipment; human resource; competence; planning; vehicle inspections; defect reporting and rectification; environmental requirements for waste disposal; staff training; licences (MOT)

4 **Understand how to control the maintenance of a vehicle fleet**

Maintenance control systems selection criteria: eg type of operation, fleet type, fleet size, cost, location of fleet, power by the hour contract

Fleet maintenance control systems: eg centralised, decentralised, manual card operation, computerised operation, computer-based systems and relevant software and hardware

Planning and controlling fleet maintenance: driver defect reporting; vehicle inspection reporting; vehicle maintenance servicing schedules; vehicle testing; maintaining vehicle records

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Understand the legal and operational implications of a vehicle maintenance contract	1.1 explain three different types of vehicle maintenance contract and evaluate their legal and operational implications 1.2 discuss the methods used to satisfy the requirements of a vehicle maintenance contract 1.3 assess the suitability of a vehicle maintenance contract to meet specific requirements
LO2 Understand fleet maintenance management systems	2.1 evaluate different management systems for fleet maintenance and identify the criteria for selecting a management system 2.2 design a fleet maintenance management system to satisfy a customer's requirements
LO3 Understand the legal implications relating to vehicle maintenance	3.1 explain the legal requirements when undertaking fleet maintenance 3.2 discuss the implications and processes needed to satisfy legal requirements
LO4 Understand how to control the maintenance of a vehicle fleet	4.1 produce criteria for the selection of a maintenance control system 4.2 evaluate a control system for the maintenance of a vehicle fleet 4.3 explain the procedures used when planning and controlling the maintenance of a vehicle fleet.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017 © Pearson Education Limited 2017

Guidance

Links

This unit can be linked with *Unit 74: Vehicle Fault Diagnosis* and *Unit 75: Vehicle Technology*.

Essential requirements

Learners will need access to a range of relevant legal and operational documentation.

Employer engagement and vocational contexts

It would be helpful for delivery if learners visited one or two industrial locations that use different approaches to vehicle maintenance. Alternatively, suitable guest speakers might be invited to provide an overview of their fleet vehicle maintenance operations.

Unit 78: Automotive Accident Investigation

Unit code: L/601/1368

Level: 5

Credit value: 15

Aim

This unit gives learners an in-depth appreciation of the principles and techniques used for accident investigation and reconstruction.

Unit abstract

This unit will develop learners' understanding of the forces acting on a vehicle in motion and during a collision. Learners will then investigate brake and tyre characteristics and the influence that they have on a vehicle. The final learning outcome will develop the skills used when analysing and reconstructing an accident.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand the forces acting on a vehicle when in motion and during a collision

2 Understand the influence of vehicle brake characteristics on the behaviour of a vehicle

3 Understand the influence of vehicle tyre characteristics on the behaviour of a vehicle

4 Be able to apply accident reconstruction techniques.

Unit content

1 **Understand the forces acting on a vehicle when in motion and during a collision**

Forces and motion: applications of mass, weight, force, Newton's Laws of motion and equations of motion on a moving vehicle; determination and effect of tractive effort and tractive resistance

Effect of friction: definition of friction and the co-efficient of friction; factors affected eg skidding, sliding, rolling; calculations eg to determine stopping distances, cornering speeds, effects of gradient, rolling and air friction; deceleration and braking theory; brake efficiency; brake ratio

Vehicle collision: collision with moving and stationary bodies; principle of conservation of momentum; principle of conservation of energy; calculation of impact speeds; interpretation of projective behaviour eg objects projected from a vehicle on impact; load transfer

2 **Understand the influence of vehicle brake characteristics on the behaviour of a vehicle**

Types of brake circuits: single line braking circuit; front and rear split circuit; diagonally split circuit; H-split; L-split; full dual circuit; air/hydraulic circuits; air brake circuits; anti-lock braking circuit

Types of pressure valves: pressure limiting valves; load sensing valve; inertia sensing valve

Characteristics of brake fluid: types of fluid; constituents; contamination boiling point; vapour lock point

Brake defects: braking faults eg effect of air in brake fluid, temporary loss of breaking, air contamination, heat soak, uneven braking, brake fade, drum expansion

Legal requirements: legal requirements with respect to hydraulic and air braking systems eg the design and use of braking systems are governed by two sets of regulations, the Construction and Use regulations, and the Economic Commission for Europe (ECE) Directives

3 **Understand the influence of vehicle tyre characteristics on the behaviour of a vehicle**

Tyre markings: car and truck markings; nominal rim diameter; nominal section width; overall diameter; section height; load index; speed index; nominal aspect ratio; load capacity

Vehicle handling and tyre behaviour: slip angle; self-aligning torque; cornering force; centrifugal force; cornering power; instantaneous centre; neutral steer; understeer; oversteer; effects of fault suspension dampers on vehicle handling

Factors affecting a*dhesion*: co-efficient of friction; effect on adhesion as retardation is increased on various types of surface and weather conditions; skidding; aquaplaning

Tyre construction: cross-ply; radial-ply; bias-belted; bead; carcass; sidewall; bracing belt; tyre tread materials

Tyre defects: under inflation; over inflation; lumps; bulges; casing break-up; cuts; exposed cords; inspection of tyre valve; reasons for tyre blow-out; effects of impact or concussion damage

Legal requirements: legal requirements of tyres eg be free from any cuts bigger than 25 mm or 10% of their section width, especially the side walls, be free from any cuts deep enough to reach the cords or plies, have no evidence of lumps, bulges or tears caused by any separation or structural failure, have no exposed plies or cords, have the original groove bases visible in the tread area, have a minimum of 1 mm depth of tread pattern across ¾ of the breadth of the tread (goods/passenger vehicles only), have the remaining ¼ of the breadth of the tyre with a visible tread pattern, have a tread depth not less than 1.6 mm across the centre of the tyre tread (cars)

4 **Be able to apply accident reconstruction techniques**

Tyre marks and vehicle damage: skid marks; scuff marks; deceleration scuff and tyre prints; debris; secondary impact; vehicle position before and after impact

Accident scene construction plans: the immediate scene, intermediate scene, extended scene; sketch plans and scale plans; triangulation, base line and offsets; use of computer software eg CAD

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017 © Pearson Education Limited 2017

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Understand the forces acting on a vehicle when in motion and during a collision	1.1 carry out calculations to determine the forces acting upon a vehicle in motion 1.2 explain the effect of friction on the motion of a vehicle 1.3 evaluate the effects of a vehicle collision
LO2 Understand the influence of vehicle brake characteristics on the behaviour of a vehicle	2.1 analyse different types of brake circuits and explain the effect of circuit failure on brake performance when one circuit fails 2.2 explain the operation of different types of pressure valves 2.3 assess the different characteristics of brake fluid 2.4 explain the different types of brake defects 2.5 explain the legal requirements with regard to vehicle braking systems
LO3 Understand the influence of vehicle tyre characteristics on the behaviour of a vehicle	3.1 explain the different types of tyre markings 3.2 discuss the factors affecting vehicle handling and tyre behaviour 3.3 discuss the factors affecting adhesion 3.4 recognise tyre construction and determine types of tyre defects 3.5 interpret the legal requirements for tyres
LO4 Be able to apply accident reconstruction techniques	4.1 evaluate the relevance of vehicle debris and tyre markings at the scene of an accident 4.2 produce accident scene construction plans.

Guidance

Links

This is a stand alone unit.

Essential requirements

Centres must provide access to suitable and relevant automotive accident data.

Employer engagement and vocational contexts

Delivery of this unit will benefit from centres establishing strong links with employers willing to contribute to the delivery of teaching, work-based placements and/or detailed case study materials.

Unit 79: Vehicle Electronics

Unit code: T/601/1364

Level: 4

Credit value: 15

Aim

This unit will develop learners' understanding of vehicle electrical and electronic systems, circuits and components and will develop the skills needed to carry out tests, find faults and repair systems.

Unit abstract

The increasing use of electronic circuitry in motor vehicle control systems has contributed to advances in safety, comfort and economy. New applications, often incorporating microprocessor hardware, continue to be introduced. It is thus essential for motor vehicle engineers to be familiar with the operation of electronic circuits and methods of fault diagnosis.

Learning outcome 1 will provide learners with knowledge of electronic principles, circuit components and test procedures. In learning outcome 2, learners are introduced to the various types of sensors, actuators and display units used in motor vehicle control and driver information systems. Learning outcome 3 provides knowledge of microprocessor hardware applications and the suppression methods used to prevent interaction between systems. Learning outcome 4 will provide learners with the opportunity to apply their knowledge of vehicle electronics and circuitry to the systematic testing and fault diagnosis of vehicle control and information systems.

Learning outcomes

On successful completion of this unit a learner will:

1 Be able to analyse vehicle electrical and electronic circuits

2 Understand the operation of vehicle sensors, actuators and display units

3 Understand the operation of microprocessor hardware and suppression methods used in vehicle circuits

4 Be able to carry out systematic fault diagnosis and repairs on vehicle electronic systems.

Unit content

1 **Be able to analyse vehicle electrical and electronic circuits**

Electrical calculations: voltage; emf; current; power; resistance; capacitance; inductance; series and parallel circuits

Semiconductor devices: electrical properties and characteristics of semiconductor material; P-N junction diode; Zener diode; N-P-N junction transistor; P-N-P junction transistor and thyristor; analyse the operation of a semiconductor based circuit, eg electronic ignition amplifier

Circuit diagrams: electrical and electronic component and circuit symbols; circuit diagram layouts

Systematic testing: test procedures; correct use of multimeters and oscilloscope for measuring circuit and component values

2 **Understand the operation of vehicle sensors, actuators and display units**

Sensors: principles of operation and electrical characteristics of sensors used in vehicles eg sensors used in anti-lock braking systems (ABS), electronic fuel injection (EFI), engine management systems, airbags, security, driver information and vehicle condition monitoring systems); relevant test procedures for sensors

Actuators: principles of operation and electrical characteristics of vehicle actuators eg relays, solenoids, electro-hydraulic/pneumatic valves, rotary actuators, stepper motors; relevant tests procedures for actuators

Information display devices: types of devices eg analogue gauges, light emitting diodes, liquid crystal displays, vacuum fluorescent displays, cathode ray tubes; relevant test procedures for displays

3 **Understand the operation of microprocessor hardware and suppression methods used in vehicle circuits**

Microprocessor hardware: implementation, operation and relevant developments of microprocessor systems in vehicles eg computer area network (CAN) bus links; packaging; microcontrollers; integrated circuits; reliability; electromagnetic compatibility

Suppression methods: resistive suppression of oscillations; screening; use of inductors; capacitors and filter networks in interference suppression

4 **Be able to carry out systematic fault diagnosis and repairs on vehicle electronic systems**

Systematic testing: testing of input/output sensors, cables, supplies, earths, output actuators, display devices and microprocessor systems

Self diagnosis: signal plausibility checks; open and short circuit checks; processor operation and memory test routines; error/trouble codes; standardisation of connectors and codes; continuity checks; sensor output; resistance checks

Fault repairs: correct procedures for removal/refitting eg following manufacturer’s recommendations; repair and replacement of system components

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Be able to analyse and test vehicle electrical and electronic circuits	1.1 carry out calculations to solve problems in series and parallel automotive electrical circuits 1.2 explain the properties and characteristics of common semiconductor devices 1.3 read and interpret electrical and electronic circuit diagrams 1.4 perform systematic testing of vehicle electronic systems and record results
LO2 Understand the operation of vehicle sensors, actuators and display units	2.1 explain the principles of operation and electrical characteristics of different sensors when used in vehicles 2.2 explain the principles of operation and electrical characteristics of different actuators when used in vehicles 2.3 examine the operation and relevant test procedure of a driver information display device
LO3 Understand the operation of microprocessor hardware and suppression methods used in vehicle circuits	3.1 analyse microprocessor hardware operation in vehicle systems 3.2 analyse the operation of a suppression method
LO4 Be able to carry out systematic fault diagnosis and repairs on vehicle electronic systems	4.1 carry out systematic test procedures on vehicle microprocessor, sensor and suppression systems and record results 4.2 evaluate the use of a vehicle self diagnosis system 4.3 identify and repair faults on a vehicle microprocessor, sensor/actuator and suppression system.

Guidance

Links

This unit links with *Unit 74: Vehicle Fault Diagnosis* and *Unit 75: Vehicle Technology*.

Essential requirements

Learners will need access to sufficient test equipment to support a range of practical tests on vehicle electrical and electronic systems.

Employer engagement and vocational contexts

The delivery of this unit will benefit from centres establishing strong links with employers willing to contribute to the delivery of teaching, work-based placements and/or detailed case study materials.

Unit 80: Business Strategy Planning for Vehicle Operations

Unit code: A/601/5142

Level: 5

Credit value: 15

Aim

This unit aims to develop learners' understanding of the business strategy planning process and its implementation in vehicle operations.

Unit abstract

In this unit learners will investigate the impact of the external operating environment and the need to adopt organisational strategies that will ensure effective business performance. Learners will develop an understanding of the role of strategic planning in vehicle operations and the different approaches to planning and formulating strategy. They will then go on to cover the means and methods used to implement a strategy, including identifying and allocating resources. Finally learners will monitor, review and evaluate the strategic plan against benchmarked outcomes.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand strategic planning in vehicle operations

2 Understand approaches to strategy formulation in vehicle operations

3 Understand approaches to strategy implementation in vehicle operations.

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017 © Pearson Education Limited 2017

Unit content

1 **Understand strategic planning in vehicle operations**

Strategic contexts and terminology: role of strategy eg setting of missions/visions/strategic intent, objectives, goals; identification of core competencies; strategic architecture; strategic control

Evaluation of the strategy framework: reasons why and ways in which corporate planning and strategies are devised eg the creation of strategic visions, organisational mission statements, corporate planning and corporate objectives and the relationship with operational planning, objectives and target setting

Planning process: approaches to planning and formulation of strategy and objectives eg in small, medium and large organisations; the formal approach to planning compared to the ad hoc approach

Differing approaches to strategy: eg classical/rational, incremental and emergent approaches to strategy and the benefits and limitations of each

2 **Understand approaches to strategy formulation in vehicle operations**

Environmental: audit eg political, economic, socio-cultural, technological, legal and economic analysis (PESTLE), Porter's 5 force analysis, the threat of new entrants, the power of the buyer, the threat of substitutes, competitive rivalry, competition and collaboration

Internal: audit eg benchmarking, the use of McKinsey's 7S framework, SWOT, purpose, scope of activities and markets, product positions, organisational efficiency, distribution methods, operations, finance, policy and procedures

Current market: vehicle operation's position eg competitor analysis, Boston Matrix

Organisational strategy: strategic direction eg the Ansoff matrix, growth, stability, profitability, efficiency, market leadership, survival, mergers and acquisitions, expansion into the global market place

3 **Understand approaches to strategy implementation in vehicle operations**

Strategic implementation: realisation of strategic plans to operational reality eg selling the concepts, project teams, identification of team and individual responsibilities

Resource allocation: finance; human and physical resources; materials; time

Review and evaluation: evaluation of the benchmarked outcomes in a given time period of corporate, operational and individual targets

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **On successful completion of this unit a learner will:**
LO1 Understand strategic planning in vehicle operations	1.1 explain the strategic contexts and terminology of planning in a vehicle operation setting 1.2 evaluate the strategy framework in a vehicle operation 1.3 explain the role and setting of objectives in the planning process 1.4 compare the differing approaches to strategy in vehicle operation settings
LO2 Understand approaches to strategy formulation in vehicle operations	2.1 conduct an environmental and internal audit of a vehicle operation 2.2 discuss the current market for the vehicle operation 2.3 develop an organisational strategy based on the audit
LO3 Understand approaches to strategy implementation in vehicle operations	3.1 compare the roles and responsibilities for strategy implementation in two different organisations 3.2 explain the resource requirements needed to implement a new strategy for a vehicle operation 3.3 propose targets and time scales for the review and evaluation of achievement in a given organisation to monitor a given strategy.

Guidance

Links

This unit can be linked with *Unit 7: Business Management Techniques for Engineers*.

Essential requirements

There are no essential requirements for this unit.

Employer engagement and vocational contexts

The delivery of this unit will benefit from centres establishing strong links with employers willing to contribute to the delivery of teaching, work-based placements and/or detailed case study materials.

Unit 81: Vehicle Parts Management

Unit code: L/601/5145

Level: 5

Credit value: 15

Aim

This unit provides learners with an understanding of the management of vehicle parts distribution and supply in the retail sector of the motor industry.

Unit abstract

In this unit learners will explore the roles and responsibilities of parts suppliers, parts managers and franchise suppliers. They will also look at the different ways of dealing with customers. Stock management systems are investigated and learners will evaluate the different types of stock control systems. Learners will examine the function and layout of a parts department and will identify potential risks that can be found within the department. Finally, the role of advertising in a vehicle parts operation and the means of promoting a parts supplier are explored, along with the internal factors that can affect parts sales.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand the roles and responsibilities in vehicle parts supply and management

2 Understand stock management systems

3 Understand the functions and processes in a vehicle parts supplier operation

4 Understand the role of advertising and promotion in a vehicle parts operation.

Unit content

1 **Understand the roles and responsibilities in vehicle parts supply and management**

Parts supplier: manufacturers eg vehicle, component manufacturer; distributor eg dealerships, wholesaler, factor, national retail chains, DIY outlets, high street retailers, cash and carry; specialist supplier

Customer: eg retail, trade, own workshop, vehicle sales, car fleet, van fleet, commercial fleet, body repairer, fast fit, garage, service station, breakdown and recovery specialist, repair specialist, vehicle restoration specialist

Responsibilities: financial eg turnover, profitability, control of stock investment, control of costs; development of customer base and new markets eg customer care, sales promotion, after sales services; management of staff and department eg personnel issues, staffing levels, layout and maintenance of department and facilities

Franchise supplier: relationship with manufacturer; franchise agreements; obligations and responsibilities; benefits and/or disadvantages

2 **Understand stock management systems**

Efficiency: maintenance of stock eg maximum, minimum, working stock, order level, safety stock, lead time, virtual stock, stock turn, obsolete, redundant, fast moving, slow moving, captive parts, competitive parts, warranty; financial control eg stock turn ratio, cost of holding stock, cost of ordering stock, economic order quantity (EOQ), gross profit, net profit; physical stock control eg stock check and audit, categorising stock, Pareto's Law, coding stock, statistical sampling

Stock control: card systems; in-house computerised systems; online systems (electronic ordering), computer parts catalogue; just-in-time (JIT)

Computerised systems: maintenance of stock levels; automatic order generation; bar coding stock; stock and sales analysis; changes in demand

Lost sales: parts satisfaction level; increase in demand; mathematical techniques

3 **Understand the functions and processes in a vehicle parts supplier operation**

Main sections: goods inwards; goods outwards; parts storage; gangways; trade and retail sales counter and/or workshop counter; stock control; parts manager's office; sales displays; delivery and distribution methods eg road, rail, post

Factors: security of stock; capacity; health and safety; accessibility; speed of picking; limitation of stock damage; presentation; image

Documentation: delivery note; advice note; damage/discrepancy report; estimate; quotation; order; trade note; invoice; statement; credit note; stock order; emergency order; vehicle off road (VOR) order; stock audit report; warranty report

Risk assessment: liquids and chemicals eg solvents, glues, paints, oil, grease, thinners, cleaners, anti-freeze, de-icers, battery acid; machinery eg fork lift, stackers, trolley, crane; storage eg weight, bulk, access, height

4 **Understand the role of advertising and promotion in a vehicle parts operation**

Advertising media: newspapers; magazines; radio; television; other eg leaflets, mail shots, recommendations; benefits (cost, coverage, targeting, geographical, timing, impact)

Promoting: sponsorship; presentations; trade events; shows

In-house factors: staff eg presentation, knowledge, attitude, customer care; layout eg presentation, comfort, services (drinks and papers), size; service eg speed, price, efficiency and effectiveness

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017 © Pearson Education Limited 2017

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Understand the roles and responsibilities in vehicle parts supply and management	1.1 compare the role of different types of parts suppliers 1.2 explain the different approaches and methods of dealing with customers 1.3 explain the responsibilities of the parts manager 1.4 explain the obligations and responsibilities of the franchise supplier
LO2 Understand stock management systems	2.1 determine the efficiency of stock management 2.2 evaluate stock control systems 2.3 explain the benefits of a computerised stock management system 2.4 identify lost sales and new demand
LO3 Understand the functions and processes in a vehicle parts supplier operation	3.1 explain the function of the main sections of the parts department 3.2 explain factors affecting the layout of the parts department 3.3 describe the documentation used by parts suppliers 3.4 conduct a risk assessment for the parts department
LO4 Understand the role of advertising and promotion in a vehicle parts operation	4.1 evaluate the benefits of different advertising media 4.2 evaluate methods of promoting the parts supplier 4.3 discuss the in-house factors affecting parts sales.

Guidance

Links

This unit can be linked with other units such as *Unit 20: Quality and Business Improvement*

Essential requirements

There are no essential requirements for this unit.

Employer engagement and vocational contexts

It would be helpful for delivery if learners visited one or two different types of vehicle parts supplier. Alternatively, suitable guest speakers might be invited to provide an overview of the roles and responsibilities within their organisation.

Unit 82: Nuclear Technology and Radiation Safety

Unit code: **R/506/4482**

Level: **4**

Credit value: **16**

Aim

The aim of this unit is to provide scientific knowledge about the main types of radioactivity with respect to their origin, uses and safety. The uses will be considered through aspects of nuclear technology.

Unit abstract

This unit will enable learners to understand the physical principles that underpin aspects of nuclear technology in use today. The subject will be introduced and developed in an historical context and it will highlight a range of nuclear technologies that have been or are currently in use. The unit will also familiarise learners with the associated hazards of nuclear technology and the safety measures that must be employed to ensure that the technology is deployed safely.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand the nature of elemental isotopes and the forces associated with nuclear structure

2 Understand radioactivity, radioactive decay and nuclear reactions

3 Understand the applications of nuclear technology

4 Understand the interaction of radiation with biological materials.

Unit content

1 **Understand the nature of elemental isotopes and the forces associated with nuclear structure**

Atomic and nuclear structure: mass number and atomic number; nucleons; isotopes; nuclear radius; the work of Rutherford; Chadwick; the Curies; Becquerel; Fermi; Oppenheimer and Teller

Strong nuclear force and binding energy: curve of binding energy and mass deficit; stable and unstable isotopes

2 **Understand radioactivity, radioactive decay and nuclear reactions**

Radioactivity: alpha decay; beta decay; gamma decay; parent and daughter products; radioactive series; neutrino/anti-neutrino emission; weak interaction; radiation detectors eg materials, physical basis, system designs;

Radioactive decay: law of radioactive decay; basic statistical treatment; half-life; the Becquerel and the Curie; SI units for radioactive decay

Nuclear reactions: accelerators; conservation of mass number; Q values and threshold Energy

3 **Understand the applications of nuclear technology**

Energy sources and generation: slow and fast neutrons; fission and fusion; moderators; nuclear reactor types and nuclear fuel cycle; natural enrichment reactors; uranium enrichment; fission and fusion reactors; pressurised water reactors; gas cooled reactors; high temperature reactors; thermo-electric pile reactors; nuclear fuels; reprocessing; waste management strategies

Medical applications: medical isotopes for diagnostic imaging and treatment

Industrial/research applications: radioactive source generation and radiography; accelerators and high energy particle diffraction; residual stress measurement; structural analysis; ion implantation; uranium enrichment technology – diffusion; centrifuge; laser

4 **Understand the interaction of radiation with biological materials**

Effect of radiation on molecular components of human tissue: energy deposition and ionisation of biological molecules; free radicals; somatic and hereditary effects; stochastic and non-stochastic effects

Radiation safety: safety assessment; radiation units; NRPB; ICRP; NRPB dose limits; national/international radiation regulations; annual worker dose; work-place controls; absorbed dose; dose rates and dose equivalents; organ dose limits; radiation flux; inverse square law; fluence rate for radiation field

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	Assessment criteria for pass **The learner can:**
LO1 Understand the nature of elemental isotopes and the forces associated with nuclear structure	1.1 summarise the current model of atomic and nuclear structure 1.2 review the physical basis of the model of elemental isotopes and the concepts of the strong nuclear force and nuclear binding energy
LO2 Understand radioactivity, radioactive decay and nuclear reactions	2.1 explain the different types of radioactivity 2.2 explain the historical developments that led to our current understanding of radioactivity 2.3 explain the physical process that governs radioactive decay 2.4 assess the usefulness of the concept of half-life by reference to experimental work or practical applications 2.5 explain the different methods of detecting radiation 2.6 analyse nuclear reactions in the context of a laboratory, research and/or industrial applications
LO3 Understand the applications of nuclear technology	3.1 explain the principles of the different types of nuclear reactor used for electrical energy generation 3.2 analyse how radioactive isotopes are used in medicine 3.3 review the use of radioactive sources in industry
LO4 Understand the interaction of radiation with biological materials with reference to radiation safety	4.1 explain the type of interactions that may occur when ionising radiation interacts with the molecular components of tissue and the possible effects on the human body 4.2 define radiation dose, dose rate and dose equivalent rate 4.3 calculate radiation dose equivalents for selected situations 4.4 evaluate the methods and the associated regulations for minimising human exposure to ionising radiation 4.5 analyse radiation safety with reference to a safety assessment

9781446955215- Pearson BTEC Levels 4 and 5 Higher Nationals specification in Engineering – Issue 3 – November 2017

Guidance

inks

This unit is related to the PaaVQSET Level 2 (500/6152/5) and Level 3 (500/6207/4) and Level 4 (500/6155/0) NVQs in Radiation Protection. There are no pre-requisites to studying this introductory unit. The Society for Radiological Protection which is the leading UK society and registered charity promoting learning and skills in the area of radiation protection, will provide information relevant to the unit.

Essential requirements

Delivery

The unit content may be delivered through lectures, demonstrations, directed reading, case study and tutorial sessions combined with practical assignment work. In familiarising themselves with technological applications learners would benefit from links with industry and extended learner assignments.

Centres are expected to ensure that, as far as is practically possible, practical work is undertaken at or near the same time as the teaching of the corresponding theoretical work.

Assessment

Evidence for this unit can be generated through an appropriate mix of written assignment work and experimental work, subject to the resources available locally. Outcome 1 could be developed from lecture materials, directed reading, case study and assignments. Outcomes 2 and 3 could be developed through demonstration, practical work and assignments. Outcome 4 must be developed through demonstrations, practical work and assignments.

Resources

Learners will need laboratory/computer demonstrations and/or experimental facilities involving the use of radiation sources and detectors together with materials outlining the regulations and measures necessary to ensure safe handling of radioactive sources. Observation of industrial applications would help considerably to underpin the unit's ideas and concepts.