Unit 1: Analytical Methods for Engineers

Unit code: A/601/1401

QCF 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.

Unit 2: Engineering Science

Unit code: L/601/1404

QCF 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.

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.

Unit 3: Project Design, Implementation and Evaluation

Unit code: L/601/0995

QCF 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.

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.

Unit 5: Electrical and Electronic Principles

Unit code: R/601/1453

QCF 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.

Unit 7: Business Management Techniques for Engineers

Unit code: R/601/1467

QCF 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

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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.

Unit 27: Personal and Professional Development

Unit code: T/601/0943

QCF 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)

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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.

Unit 29: Work-based Experience

Unit code: D/601/0998

QCF 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.

Unit 37: Management of Projects

Unit code: J/601/0302

QCF 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.

Unit 39: Electronic Principles

Unit code: J/601/1448

QCF 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.

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-βA = 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

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.

Unit 59: Advanced Mathematics for Engineering

Unit code: K/601/1412

QCF 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.

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.

Unit 101: Electrical and Electronic Principles

Unit code: J/600/0255

QCF Level 3: BTEC National

Credit value: 10

Guided learning hours: 60

Aim and purpose

This unit aims to give learners an understanding of the underlying physical principles on which electrical and electronic devices and circuits depend. It will also develop skills in the application of circuit theory.

Unit introduction

The modern world relies on electrical and electronic devices – from mobile telephones to jet aeroplanes, these devices have had an enormous impact on the way we live today. Without early engineers such as Faraday and Lenz, who studied the then new concept of electricity, many of the inventions we now take for granted would not have been developed.

The unit starts by developing and extending learners' understanding of fundamental electrical and electronic principles through analysis of simple direct current (DC) circuits. Learners are then taken through the various properties and parameters associated with capacitance and inductance, before finally considering the application of single-phase alternating current (AC) theory. The unit will encourage learners to take an investigative approach through practical construction, measurement and testing of circuits and, where applicable, the use of computer-based circuit analysis and simulation.

For learners wishing to follow an electrical/electronic programme this unit is an essential building block that will provide the underpinning knowledge required for further study of electrical and electronic applications.

Learning outcomes

On completion of this unit a learner should:

1 Be able to use circuit theory to determine voltage, current and resistance in direct current (DC) circuits

2 Be able to carry out measurements and calculations on DC circuits that contain capacitors

3 Know the principles and properties of magnetism

4 Be able to use single-phase alternating current (AC) theory.

Unit content

1 Be able to use circuit theory to determine voltage, current and resistance in direct current (DC) circuits

DC circuit theory: voltage eg potential difference, electromotive force (emf); resistance eg conductors and insulators, resistivity, temperature coefficient, internal resistance of a DC source; circuit components (power source eg cell, battery, stabilised power supply; resistors eg function, types, values, colour coding; diodes eg types, characteristics, forward and reverse bias modes); circuit layout (DC power source, resistors in series, resistors in parallel, series and parallel combinations); Ohm's law, power and energy formulae eg $V = IR$, $P = IV$, $W = Pt$, application of Kirchhoff's voltage and current laws

DC networks: networks with one DC power source and at least five components eg DC power source with two series resistor and three parallel resistors connected in a series parallel arrangement; diode resistor circuit with DC power source, series resistors and diodes

Measurements in DC circuits: safe use of a multimeter eg setting, handling, health and safety; measurements (circuit current, voltage, resistance, internal resistance of a DC power source, testing a diode's forward and reverse bias)

2 Be able to carry out measurements and calculations on DC circuits that contain capacitors

Capacitors: types (electrolytic, mica, plastic, paper, ceramic, fixed and variable capacitors); typical capacitance values and construction (plates, dielectric materials and strength, flux density, permittivity); function eg energy stored, circuits (series, parallel, combination); working voltage

Charging and discharging of a capacitor: measurement of voltage, current and time; tabulation of data and graphical representation of results; time constants

DC network that includes a capacitor: eg DC power source with two/three capacitors connected in series, DC power source

3 Know the principles and properties of magnetism

Magnetic field: magnetic field patterns eg flux, flux density (B), magnetomotive force (mmf) and field strength (H), permeability, B/H curves and loops; ferromagnetic materials; reluctance; magnetic screening; hysteresis

Electromagnetic induction: principles eg induced electromotive force (emf), eddy currents, self and mutual inductance; applications (electric motor/generator eg series and shunt motor/generator; transformer eg primary and secondary current and voltage ratios); application of Faraday's and Lenz's laws

4 Be able to use single-phase alternating current (AC) theory

Single phase AC circuit theory: waveform characteristics eg sinusoidal and non-sinusoidal waveforms, amplitude, period time, frequency, instantaneous, peak/peak-to-peak, root mean square (rms), average values, form factor; determination of values using phasor and algebraic representation of alternating quantities eg graphical and phasor addition of two sinusoidal voltages, reactance and impedance of pure R, L and C components

AC circuit measurements: safe use of an oscilloscope eg setting, handling, health and safety; measurements (periodic time, frequency, amplitude, peak/peak-to-peak, rms and average values); circuits eg half and full wave rectifiers

Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

Grading criteria		
To achieve a pass grade the evidence must show that the learner is able to:	**To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:**	**To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:**
P1 use DC circuit theory to calculate current, voltage and resistance in DC networks	**M1** use Kirchhoff's laws to determine the current in various parts of a network having four nodes and the power dissipated in a load resistor containing two voltage sources	**M1** analyse the operation and the effects of varying component parameters of a power supply circuit that includes a transformer, diodes and capacitors
P2 use a multimeter to carry out circuit measurements in a DC network	**M2** evaluate capacitance, charge, voltage and energy in a network containing a series-parallel combination of three capacitors	**D2** evaluate the performance of a motor and a generator by reference to electrical theory.
P3 compare the forward and reverse characteristics of two different types of semi-conductor diode [IE4]	**M3** compare the results of adding and subtracting two sinusoidal AC waveforms graphically and by phasor diagram.	
P4 describe the function of different types of capacitors		
P5 carry out an experiment to determine the relationship between the voltage and current for a charging and discharging capacitor [IE3]		
P6 calculate the charge, voltage and energy values in a DC network for both three capacitors in series and three capacitors in parallel		
P7 describe the characteristics of a magnetic field		
P8 describe the relationship between flux density (B) and field strength (H)		

Grading criteria		
To achieve a pass grade the evidence must show that the learner is able to:	**To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:**	**To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:**
P9 describe the principles and applications of electromagnetic induction		
P10 use single phase AC circuit theory to determine the characteristics of a sinusoidal AC waveform [IE3]		
P11 use an oscilloscope to measure and determine the inputs and outputs of a single phase AC circuit [SM3].		

PLTS: This summary references where applicable, in the square brackets, the elements of the personal, learning and thinking skills applicable in the pass criteria. It identifies opportunities for learners to demonstrate effective application of the referenced elements of the skills.

Key			
	IE – independent enquirers	RL – reflective learners	SM – self-managers
	CT – creative thinkers	TW – team workers	EP – effective participators

Unit 103: Further Mathematics for Engineering Technicians

Unit code: H/600/0280

QCF Level 3: BTEC Nationals

Credit value: 10

Guided learning hours: 60

Aim and purpose

This unit aims to enhance learners' knowledge of the mathematical principles used in engineering, enabling them to pursue further study on a higher education qualification in engineering.

Unit introduction

Mathematics is an essential tool for any electrical or mechanical engineering technician. With this in mind, this unit emphasises the engineering application of mathematics. For example, learners could use an integral calculus method to obtain the root mean square (RMS) value of a sine wave over a half cycle.

The first learning outcome will extend learners' knowledge of graph plotting and will develop the technique of using a graph to solve (find the roots of), for example, a quadratic equation.

Learning outcome 2 involves the use of both arithmetic and geometric progressions for the solution of practical problems. The concept of complex numbers, an essential tool for electrical engineers considering, is also introduced.

Learning outcome 3 considers the parameters of trigonometrical graphs and the resultant wave when two are combined. The use of mathematical formulae in the latter half of this learning outcome enables a mathematical approach to wave combination to be considered.

Finally, in learning outcome 4, calculus techniques are further developed and used to show their application in engineering.

Learning outcomes

On completion of this unit a learner should:

1 Be able to use advanced graphical techniques

2 Be able to apply algebraic techniques

3 Be able to manipulate trigonometric expressions and apply trigonometric techniques

4 Be able to apply calculus.

Unit content

1 Be able to use advanced graphical techniques

Advanced graphical techniques: graphical solution eg of a pair of simultaneous equations with two unknowns, to find the real roots of a quadratic equation, for the intersection of a linear and a quadratic equation, non-linear laws such as ($y = ax^2 + b$, $y = a + \frac{b}{x}$), by the use of logarithms to reduce laws of type $y = ax^n$ to straight line form, of a cubic equation such as $2x^3 - 7x^2 + 3x + 8 = 0$, recording, evaluating and plotting eg manual, computerised

2 Be able to apply algebraic techniques

Arithmetic progression (AP): first term (a), common difference (d), nth term eg $a + (n - 1)d$; arithmetic series eg sum to n terms, $S_n = \frac{n}{2}\{2a + (n-1)d\}$

Geometric progression (GP): first term (a), common ratio (r), nth term eg $a\,r^{n-1}$; geometric series eg sum to n terms, $S_n = \frac{a(r^n - 1)}{r - 1}$, sum to infinity $S_\infty = \frac{a}{1 - r}$; solution of practical problems eg compound interest, range of speeds on a drilling machine

Complex numbers: addition, subtraction, multiplication of a complex number in Cartesian form, vector representation of complex numbers, modulus and argument, polar representation of complex numbers, multiplication and division of complex numbers in polar form, polar to Cartesian form and vice versa, use of calculator

Statistical techniques: review of measure of central tendency, mean, standard deviation for ungrouped and grouped data (equal intervals only), variance

3 Be able to manipulate trigonometric expressions and apply trigonometric techniques

Trigonometrical graphs: amplitude, period and frequency, graph sketching eg $\sin x$, $2 \sin x$, $\frac{1}{2} \sin x$, $\sin 2x$, $\sin \frac{1}{2} x$ for values of x between 0 and 360°; phase angle, phase difference; combination of two waves of the same frequency

Trigonometrical formulae and equations: the compound angle formulae for the addition of sine and cosine functions eg $\sin (A \pm B)$; expansion of $R \sin (\omega t + \alpha)$ in the form $a \cos \omega t + b \sin \omega t$ and vice versa

4 Be able to apply calculus

Differentiation: review of standard derivatives, differentiation of a sum, function of a function, product and quotient rules, numerical values of differential coefficients, second derivatives, turning points (maximum and minimum) eg volume of a rectangular box

Integration: review of standard integrals, indefinite integrals, definite integrals eg area under a curve, mean and RMS values; numerical eg trapezoidal, mid-ordinate and Simpson's rule

Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

Assessment and grading criteria		
To achieve a pass grade the evidence must show that the learner is able to:	**To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:**	**To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:**
P1 use a graphical technique to solve a pair of simultaneous linear equations [CT5]	**M1** use the laws of logarithms to reduce an engineering law of the type $y = ax^n$ to straight line form, then using logarithmic graph paper, plot the graph and obtain the values for the constants a and n	**D** using a graphical technique determine the single wave resulting from a combination of two waves of the same frequency and then verify the result using trigonometrical formulae
P2 solve a practical engineering problem involving an arithmetical progression	**M2** use complex numbers to solve a parallel arrangement of impedances giving the answer in both Cartesian and polar form	**D2** use numerical integration and integral calculus to analyse the results of a complex engineering problem.
P3 solve a practical engineering problem involving geometric progression	**M3** use differential calculus to find the maximum/minimum for an engineering problem.	
P4 perform the two basic operations of multiplication and division to a complex number in both rectangular and polar form, to demonstrate the different techniques		
P5 calculate the mean, standard deviation and variance for a set of ungrouped data [IE4]		
P6 calculate the mean, standard deviation and variance for a set of grouped data [IE4]		
P7 sketch the graph of a sinusoidal trigonometrical function and use it to explain the terms and describe amplitude, periodic time and frequency		

Assessment and grading criteria			
To achieve a pass grade the evidence must show that the learner is able to:		**To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:**	**To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:**
P8	use two of the compound angle formulae and verify their relationship		
P9	find the differential coefficient for three different functions to demonstrate the use of function of a function and the product and quotient rules		
P10	use integral calculus to solve two simple engineering problems involving the definite and indefinite integral.		

PLTS: This summary references where applicable, in the square brackets, the elements of the personal, learning and thinking skills applicable in the pass criteria. It identifies opportunities for learners to demonstrate effective application of the referenced elements of the skills.

Key	IE – independent enquirers	RL – reflective learners	SM – self-managers
	CT – creative thinkers	TW – team workers	EP – effective participators

Unit 112: Computer Programming Techniques

Unit code: D/602/2231

QCF Level: 4

Credit value: 15

Aim

This unit aims to develop learners' understanding of computer programming techniques and will enable them to design and develop programs for a variety of applications.

Unit abstract

In this unit learners will design and develop program code in order to produce programs to a desired standard. They will use construct programs from designs, using appropriate functions and procedures. The unit will enable learners to produce and correctly present both user and technical documentation for programs. They will also construct and use test data and use appropriate techniques for detecting errors.

Programs should be written to defined quality standards and problem solving tools (structure diagrams, pseudo code etc) should be used. Emphasis should be placed on the need for modularity and an indication should be given of the link between modularity and object-based development.

Learning outcomes

On successful completion of this unit a learner will:

1 Be able to design and develop code using structured programming methods

2 Be able to use modularisation appropriate to the chosen programming language

3 Be able to produce appropriate documentation for a given program application

4 Be able to create and apply appropriate test schedules

Unit content

1 **Be able to design and develop code using structured programming methods**

Storage: the concepts of data storage within a computer program, using variables, constants and literals; for a third generation language, the pre-defined data types, integers, floating-point, character, Boolean (logical), strings, 1D and 2D arrays of simple types, and simple files, consequences of using these types, and the available operators within the supplied language

Control structures: identify and select appropriate iterative and selection structures when writing simple programs

Programming language syntax: the facilities and rules of the language (operators, I/0 commands etc)

Program design: employment of an algorithmic approach for the development of a solution to a problem (structure charts, pseudo code etc); producing tested programs to meet given specifications

Programming standards and practice: use of comments; code layout eg consistent indentation and descriptive identifiers

2 **Be able to use modularisation appropriate to the chosen programming language**

Use of functions/procedures: use/create functions/procedures both pre-defined and user-defined, map structured design onto a program using functions/procedures

Scope of variables: global, local, static and external variables

Parameters: passing data by value and reference, using return values

3 **Be able to produce appropriate documentation for a given program application**

Presentation of documentation: software applications (word processor or graphics); analysis, design and implementation documentation; professional standards; needs of industry

User documentation: user documentation for specified programming applications; purpose and operation of the program developed

Program documentation: documentation that covers technical aspects of a given programming application including algorithms implemented, data table, syntax (selection, iteration) structures used, user interface methods adapted

4 **Be able to create and apply appropriate test schedules**

Error types: semantic, syntax and run-time

Test documentation: test plan and related evidence of testing (may include reading sample inputs from a file and/or writing test results to a file)

Test data and schedules: black box, white box and dry testing

Error detection techniques: compiler and linker error messages, debugging tools and structured walk-through

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 develop code using structured programming methods	1.1 select appropriate pre-defined data types 1.2 use simple input/output and appropriate operators with the above 1.3 use appropriate selection structures and loop structures for the given task 1.4 produce programs to desired standards
LO2 Be able to use modularisation appropriate to the chosen programming language	2.1 construct a program from a design and use appropriate functions/procedures 2.2 demonstrate the effect of scope and life-time of variables 2.3 pass data effectively between modules
LO3 Be able to produce appropriate documentation for a given program application	3.1 produce user documentation for a completed programming application including the user interface design 3.2 develop technical documentation for a predescribed program application
LO4 Be able to create and apply appropriate test schedules	4.1 demonstrate discrimination between semantic and syntax errors 4.2 produce test documentation 4.3 successfully construct and use test data and schedules to detect logic errors 4.4 use appropriate techniques for detecting errors

Unit 113: Principles and Applications of Microcontrollers

Unit code: Y/602/2230

QCF Level: 4

Credit value: 15

Aim

This unit will provide learners with an understanding of the applications of microcontroller-based systems and will develop the skills required to design, write and test software and interface such systems.

Unit abstract

In this unit learners will investigate the different types of microcontroller device and the wide range of applications of embedded control systems. Learners will design software and will use computer packages to write programs for a microcontroller-based system in order to implement a given specification. They will also use simulation tools to test and debug the software and will program and interface a microcontroller in order to implement a design.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand microcontroller-based systems

2 Be able to produce software for a microcontroller-based system

3 Be able to interface microcontroller-based systems

Unit content

1 **Understand microcontroller-based systems**

Types of microcontroller device: comparison based on the features of the family of PIC devices (clock speeds, internal architecture, on board memory, I/O ports, instruction size and type, interrupt facilities, additional features (eg A/D converters, oscillators and timers), package types)

Applications: use of embedded control systems in computer systems (mouse, keyboard, modem, fax card, sound card), domestic systems (door locks, air conditioning, TV remote controls, appliances), telecommunications (cellular phones, pagers, answering machines), automotive (keyless entry, anti-lock braking, engine management, air bags) office automation (copiers, printers, fax), industrial control (machinery)

2 **Be able to produce software for a microcontroller-based system**

Design software: algorithms in the form of a structure chart showing actions and conditions or in pseudo code (structured English) in sufficient detail to allow coding to proceed

Specification: use of specifications that require modularisation and the passing of data between modules

Write programs: programs written in a form that follows directly from the design; programs written in an assembly language (eg MPLAB) and then assembled using an appropriate procedure

Test software: suitable test data (eg inputs and expected outputs) prepared prior to running programs and test results documented; use of software tools (such as debugger, single-step and breakpoints) to identify errors; changes to program code or structure carried out where necessary

3 **Be able to interface microcontroller-based systems**

Input/output connection: set up of the port control registers for input or output connection; understanding of the 'TRIS' command; software design of input/output; use of programs to interface typical I/O peripherals to a microcontroller (eg as could be found on a standard project application board), including switches, LEDs, 7-segment displays, stepper motor, buzzers, traffic lights

Practical project: design and build software to realise an assigned project to operate the external peripherals using both input and output devices on the applications board to a given specification; software design fully documented and the appropriately programmed microcontroller demonstrated with the available peripheral devices operating to specification

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 microcontroller-based systems	1.1 compare types of microcontroller devices 1.2 investigate three typical applications of microcontroller-based systems
LO2 Be able to produce software for a microcontroller-based system	2.1 design software to a given specification using a structured design technique 2.2 write programs to implement the specification using an appropriate computer package 2.3 test and de-bug software, using appropriate simulation tools, to ensure it meets the given specification
LO3 Be able to interface microcontroller-based systems	3.1 implement the design by programming a suitable microcontroller 3.2 test and de-bug using the microcontroller's programmable ports connected to an appropriate project applications board

Unit 117: Digital and Analogue Devices and Circuits

Unit code: F/602/2237

QCF Level: 5

Credit value: 15

Aim

This unit aims to develop the knowledge and skills needed to design and test DC power supply systems, operational amplifier circuits and digital electronic circuits.

Unit abstract

This unit provides learners with a practical understanding of a range of integrated circuit operational amplifiers and digital devices and circuits. Learners will investigate the design and operation of DC power supplies. They will then analyse the applications of operational amplifiers, before designing and testing operational amplifier circuits. Finally, the unit will enable learners to design, construct and test digital electronic circuits.

Learning outcomes

On successful completion of this unit a learner will:

1 Be able to design, test and evaluate electronic DC power supply systems

2 Be able to design and test operational amplifier circuits

3 Be able to design, construct and test digital electronic circuits.

Unit content

1 **Be able to design, test and evaluate electronic DC power supply systems**

Operation of DC power supplies: linear regulated power supplies (simple zenerd, series transistor and IC regulators); switched mode power supplies; practical circuits in use in modern equipment

Design a linear power supply: input voltages; output voltage and current; line and load regulation; identify devices, passive component values and circuit connections

Test a linear power supply: from test results, graphs of $V_{out} \sim V_{in}$ and $V_{out} \sim I_{out}$ line and load regulation calculated

2 **Be able to design and test operational amplifier circuits**

Operational amplifier as a device: properties of the ideal operational amplifier eg very high gain, infinite input impedance, negligible voltage difference between inputs

Application circuits: comparator inverting amplifier; non-inverting amplifier; buffer amplifier (voltage follower); differential amplifier; summing amplifier; derivation of relationship between input and output voltages

Design: circuits designed to meet given specifications; use of computer simulation software to confirm correct operation

Tests: designed build circuits using prototype board or circuit trainers and test, using appropriate test equipment, to confirm that they meet the specification; draw up a schedule of test data with proposed input signals and expected output signals before testing

3 **Be able to design, construct and test digital electronic circuits**

Digital electronic devices: logic families – TTL, CMOS eg 4000 and 74 series; comparison between families (speed, power, input and output current, power supply); interfacing between different families; scales of integration (SSI, MSI, LSI, VLSI); programmable devices (PROM, PAL, PLA)

Design combinational circuits: use an appropriate design technique (Karnaugh mapping); solutions using a single type of gate eg NAND only; specifications requiring solutions with no less than four inputs and one output; simulation using computer software to confirm correct operation

Design sequential circuits: use appropriate design techniques; specifications with no less that seven states eg decade counter; simulation using computer software to confirm correct operation

Test: circuits designed for this outcome should be built using prototype boards or circuit trainers and tested, using appropriate test equipment, to confirm that they meet the specifications; a schedule of test data with proposed inputs and expected outputs should be drawn up before testing

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, test and evaluate electronic DC power supply systems	1.1 evaluate the operation of different types of DC power supply 1.2 design and test a linear power supply to meet a given specification
LO2 Be able to design and test operational amplifier circuits	2.1 evaluate the operational amplifier as a device 2.2 describe different operational amplifier application circuits 2.3 design three operational amplifier circuits 2.4 test operational amplifier circuits
LO3 Be able to design, construct and test digital electronic circuits	3.1 compare different digital electronic device families 3.2 design and construct combinational and sequential digital electronic circuits using logic devices 3.3 test digital electronic circuits

Unit 118: Telecommunications Principles

Unit code: T/602/2249

QCF Level: 5

Credit value: 15

Aim

This unit aims to develop learners' understanding of the principles and characteristics of telecommunications systems.

Unit abstract

This unit covers the principles of communicating at a distance. It considers the three elements required for the transfer of information, ie the source (transmitter), channel (link) and sink (receiver).

The use of practical/imperfect channels and the presence of interference in the form of electrical noise are considered. The bandwidth of typical signals is also covered with respect to the available portions of the complete electromagnetic spectrum. The unit also covers the requirement for the modulation of information and multiplexing techniques in both analogue and digital format. The characteristics of telecommunications traffic and queuing theory are considered, along with the mathematical tools and computer modelling systems required for analysis and methods of controlling congestion.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand the requirements of communication systems

2 Understand communication channels and their characteristics

3 Understand modulation and multiplexing techniques used for analogue and digital signals

4 Understand the characteristics of communications traffic.

Unit content

1 **Understand the requirements of communication systems**

Elements of analogue and digital communication systems: the transmitter (information source), the channel and the receiver eg wired and wireless systems; simplex, duplex and half-duplex methods

Characteristics of electro-magnetic waves: frequency (f), wavelength (λ) and velocity (v) and their interrelationship; the electro-magnetic spectrum and frequency/wavelength allocations

Signal spectra: time and frequency domains; fundamental and harmonic frequencies; complex waveforms; digital signals eg unipolar, bipolar, return-to-zero (RTZ), non-return-to-zero (NRZ)

Logarithmic relationships: the need for logarithmic representation; the Decibel and its common derivatives (dBm, dBW and dBR) and typical applications including link budgets

2 **Understand communication channels and their characteristics**

Sources and effects of noise: sources eg internal/external, natural/man-made; types eg Johnson, Shott, Partition; cumulative effects in cascaded/sequential systems; signal-to-noise ratio; noise figure and noise factor; noise temperature

Noise calculations: eg thermal/Johnson noise, signal-to-noise ratio, noise figure, noise factor

Bandwidth and information capacity: Shannon-Hartley theorem eg relationship to the available bandwidth and the signal-to-noise ratio; bandwidth requirements for typical applications (voice, radio and television broadcasting); the implications for both analogue and digital signals

Channel impairments: attenuation and other losses; bandwidth limitation; phase delay; effects on complex signals; inter-symbol interference; bit error rates (typical examples)

3 **Understand modulation and multiplexing techniques used for analogue and digital signals**

Analogue modulation methods: amplitude/frequency/phase; pulse modulation methods eg pulse amplitude (PAM), pulse position (PPM), pulse duration/width (PDM/PWM)

Modulation methods for digital signals over analogue networks: eg amplitude shift keying (ASK), frequency shift keying (FSK), phase shift keying (PSK), quaternary phase shift keying (QPSK), quaternary amplitude modulation (QAM)

Digital modulation methods: pulse code modulation (PCM); delta modulation; adaptive delta modulation

Multiplexing techniques: space division; frequency division; time division; wavelength division

4 **Understand the characteristics of communications traffic**

Telecommunications traffic over circuit switched networks: call duration; call holding times; call arrival times (coincidence); busy hour; grade of service

Telecommunications traffic over packet switched networks: server traffic; network traffic; congestion; congestion control techniques; the effects of delay

Mathematical formulae: Erlang B and Erlang C; Little's theorem and applications to queuing theory

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 requirements of communication systems	1.1 describe the elements of communication systems 1.2 explain the characteristics of electromagnetic waves and their application to communications systems 1.3 determine the signal spectra for the content of complex waveforms 1.4 convert from linear to logarithmic relationships (and vice versa) and determine the overall gain/loss of typical communication systems
LO2 Understand communication channels and their characteristics	2.1 determine the sources and effect of noise found in electronic communication systems, including cumulative factors 2.2 carry out noise calculations 2.3 determine the bandwidth and expected information capacity of typical communication systems 2.4 discuss the various channel impairments and their resultant effect on the maximum system bit rate for digital systems
LO3 Understand modulation and multiplexing techniques used for analogue and digital signals	3.1 explain the need for modulation and the variety of modulation schemes used for analogue signals 3.2 discuss the modulation methods used to represent digital data over analogue networks 3.3 describe the range of digital modulation methods and typical applications 3.4 explain the reasons for multiplexing signals giving examples of the methods used
LO4 Understand the characteristics of communications traffic	4.1 evaluate the nature of telecommunications traffic carried over circuit switched networks 4.2 evaluate the nature of telecommunications traffic carried over packet switched networks 4.3 apply mathematical formulae to typical examples of telecommunications traffic

Unit 119: Data Communications and Networks

Unit code: M/602/2251

QCF Level: 4

Credit value: 15

Aim

The aim of this unit is to develop an understanding of the architecture, operation and major design issues relating to data networks.

Unit abstract

This unit covers the networking devices required for network operation and interconnection. The unit also aims to develop an appreciation of the properties of public and private switched networks (eg public switched telephone network (PSTN), packet switched data network (PSDN) and integrated services digital network (ISDN)).

Learning outcomes

On successful completion of this unit a learner will:

1 Understand data communication networks and the requirement for open systems

2 Understand the methods employed for data communication

3 Know the function and methods of control used for local area networks

4 Understand wide area networks and internet working.

Unit content

1 **Understand data communication networks and the requirement for open systems**

Types of data communication network: eg public switched telephone network (PSTN), local area networks (LANs), metropolitan area networks (MANs), wide area networks (WANs), packet switched data network (PSDN), integrated services digital network (ISDN)

Open systems interconnection (OSI) reference model: International Standards Organisation (ISO) reference model; the layered models and the function of the layers eg OSI seven layer model

Protocol suites: eg HDLC, IPX, TCP/IP

2 **Understand the methods used for data communication**

Data transmission: methods eg simplex, duplex, semi-duplex operation; Line codes eg unipolar, bipolar, return to zero (RTZ), non return to zero (NRZ), Manchester, HDB3

Asynchronous and synchronous data transmission: principles eg stop-start systems, hardware and software control, strategies for synchronisation, interface standards (RS232), advantages and disadvantages of asynchronous and synchronous methods

Error control strategies: detection methods eg parity, block check sums, cyclic redundancy checks; correction methods eg idle RQ, continuous RQ, forward error correction

3 **Know the function and methods of control used for local area networks**

LAN topologies: star; tree; bus; ring; mesh

Transmission media: copper-based eg twisted pair shielded and unshielded; coaxial (thin and thick); optical fibres; wireless systems

Media access control: eg polling, contention, token passing, carrier sensing/collision detection

LAN hardware: repeaters; bridges; routers; gateways and multiplexors

4 **Understand wide area networks and internet working**

Features of wide area networks: topologies; transmission media; public data networks (packet switched data network (PSDN), integrated services digital network (ISDN))

Switching and packet techniques: switching (Circuit, Message and Packet); packet (Datagram, Virtual Circuit)

Routing: static; dynamic

Addressing and routing: internet and X.25 addressing; Aloha; Slotted Aloha

PSTN access methods: modem modulation schemes eg amplitude shift keying (ASK), frequency shift keying (FSK), phase shift keying (PSK), quadrature phase shift keying (QPSK), CCITT standards

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 data communication networks and the requirement for open systems	1.1 explain the differing types of data communication networks and their applications 1.2 explain the concept of the ISO open systems interconnect (OSI) reference model 1.3 explain standard protocol suites and how they relate to the OSI reference model
LO2 Understand the methods used for data communication	2.1 explain the data transmission methods used for information interchange 2.2 explain the principles of asynchronous and synchronous transmission 2.3 discuss the strategies used for controlling errors in data networks
LO3 Know the function and methods of control used for local area networks	3.1 describe commonly used LAN topologies and transmission media 3.2 describe the commonly used media access control methods for LANs 3.3 describe the IEEE 802 standards for LAN classification 3.4 describe the function of LAN hardware
LO4 Understand wide area networks and internet working	4.1 explain the features of wide area networks (WANs) 4.2 explain the switching and packet techniques used in WANs 4.3 explain how routing is achieved 4.4 discuss the methods used for data communication over the PSTN

Unit 120: Radio Communication Engineering

Unit code: Y/602/4849

QCF Level: 4

Credit value: 15

Aim

This unit aims to develop learners' understanding of the systems and sub-systems involved in communication by radio.

Unit abstract

In this unit learners will investigate the way in which information is conveyed by mixing the wanted signal with a radio frequency carrier, and the methods by which the signals are generated and received. The choice of carrier frequency and the resulting effect this has on the propagation of the signal through free space is also covered, along with the causes and effects of noise in radio systems.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand amplitude and angle modulation

2 Understand the principles of radiation and propagation of transverse electromagnetic waves in the bands very low frequency (VLF) to extremely high frequency (EHF)

3 Understand the operation of radio transmitters

4 Understand the operation of radio receivers.

Unit content

1 **Understand amplitude and angle modulation**

Amplitude modulation: the need for modulation; the components of a carrier wave which may be varied; range of carrier frequencies; how modulation may be achieved; derivation of the expression for an AM wave-form; modulation factor (m); the importance of modulation factor (m); frequency spectrum and power content of AM wave-forms; representation in the time and frequency domains when modulated by a single frequency and when modulated by a complex wave-form; bandwidth requirements; commercial speech modulation; low level and high level modulation; the advantages and disadvantages of double sideband full carrier AM

Single sideband modulation: typical applications; how the carrier is suppressed by means of the balanced modulator; how one sideband is suppressed (filter and phasing methods); the importance of stability; comparison of DSB and SSB systems; power and bandwidth considerations; extensions of SSB (pilot carrier and vestigial sideband systems); typical applications

Angle modulation: the distinction between frequency and phase modulation; definition of frequency deviation; modulation index and deviation ratio; the modulation process; the number and power content of side frequencies; the use of Bessel charts/graphs; the determination of bandwidth; Carson's rule; signal-to-noise ratio; emphasis techniques; threshold levels and capture effect; the need for squelch/muting; advantages and disadvantages of angle modulation; typical applications

2 **Understand the principles of radiation and propagation of transverse electromagnetic waves in the bands very low frequency (VLF) to extremely high frequency (EHF)**

Electromagnetic radiation: the fundamentals of electromagnetic waves; the isotropic source; free space propagation; power density; the inverse square law; radiation and reception; polarisation; the reciprocity theorem; attenuation and absorption; reflection; refraction; diffraction; properties of periodic and aperiodic aerials

Electromagnetic spectrum: the complete spectrum for electromagnetic radiation (DC to cosmic rays); classification of the bands within the complete spectrum in terms of frequency and wavelength; classification and bandwidth range of each of the bands used for radio (very low frequency to extra high frequency); typical applications for each band

Modes for the propagation of radio waves: surface wave eg characteristics, typical coverage and range, limitations; sky wave eg characteristics, the ionosphere and its effects, layers, daily/seasonal/long-term variations; terms and definitions (critical frequency, maximum usable frequency, skip distance, dead zone, multiple hop); causes of fading; space wave characteristics; radio horizon (calculations involving transmitter and receiver antennae for various applications); anomalous propagation (sub-refraction, super-refraction, ducting); tropospheric scatter; extra-terrestrial communication

3 **Understand the operation of radio transmitters**

Legal requirements: eg licensing, regulatory authorities, frequency of operation, antenna effective height, power restrictions, stability tolerance, spurious emissions

Amplitude-modulated transmitters: audio stages (compression and amplitude limiters, low pass filtering for commercial speech frequencies); the modulator stage (high level and low level, balanced and unbalanced); frequency translation by mixing and harmonic multipliers; final stage power amplifier (the need for linear amplification, the need for high efficiency, maximum power requirement, suppression of harmonics)

Frequency-modulated transmitters: audio stages (amplitude limiters, low pass filtering for speech frequencies, pre-emphasis); the modulator stage (direct and indirect methods for achieving frequency modulation); frequency translation by mixing and harmonic multipliers; the final stage power amplifier (impedance matching and diplexing arrangements)

4 **Understand the operation of radio receivers**

AM tuned-radio frequency (TRF) receiver: sensitivity and selectivity; the action of the diode detector (demodulator); the TRF receiver (radio frequency amplification and the need for high Q ganged tuned circuits); adjacent channel interference; the disadvantages of the TRF (ganging difficulties and the reduction of Q at high frequencies leading to a lack of selectivity)

Superheterodyne receiver: principle of operation; mixing; frequency conversion; selection of the intermediate frequency; IF amplification; second channel (image) interference; choice of intermediate frequency; need for the RF stage; oscillator tracking problems; dual conversion; automatic gain control; demodulation of amplitude-modulated (DSB and SSB) and frequency-modulated signals; diplexing arrangements for transceiver operation

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 amplitude and angle modulation	1.1 analyse amplitude modulation 1.2 analyse single sideband amplitude modulation 1.3 analyse angle modulation
LO2 Understand the principles of radiation and propagation of transverse electromagnetic waves in the bands VLF to EHF	2.1 explain the principles of electromagnetic radiation 2.2 explain the electromagnetic spectrum in terms of frequency and wavelength 2.3 discuss the structure and nature of the ionosphere with reference to daily, seasonal and long-term changes 2.4 explain the modes of propagation of radio waves of different frequencies
LO3 Understand the operation of radio transmitters	3.1 explain the legal requirements for transmitter operation 3.2 derive a system diagram for an amplitude-modulated transmitter and explain the function of each stage 3.3 derive a system diagram for a frequency-modulated transmitter and explain the function of each stage
LO4 Understand the operation of radio receivers	4.1 draw a block diagram of an AM tuned-radio frequency (TRF) receiver and explain its operation 4.2 explain the principle of operation of the super-heterodyne receiver 4.3 explain the necessary arrangements for transceiver operation