Unit 64: Further Electrical Principles

Unit code: Y/600/7226

QCF Level 3: BTEC Nationals

Credit value: 10

Guided learning hours: 60

Unit aim and purpose

This unit gives learners the opportunity to apply practical and theoretical principles of electrical engineering to the development, manufacture and servicing of complex electrical and electronic systems.

Unit introduction

Electrical technicians need to apply practical and theoretical principles of electrical engineering to the development, manufacture and servicing of complex electrical and electronic systems.

They can expect to perform technical functions involved in assembling, installing, repairing and maintaining electrical equipment. These could include the calibration, prototyping, modification and general maintenance of electrical equipment in accordance with manufacturers' instructions and company technical procedures.

Other tasks could include using electrical test equipment on various types of instruments, equipment and systems and replacing faulty components and parts using safe working practices and precision instruments.

The unit will extend learners' understanding of simple direct current (DC) circuits that can be solved by Ohm's law and Kirchhoff's laws. This will require learners to apply advanced circuit analysis theorems such as Thévenin's, Norton's and the maximum power transfer theorems for DC networks.

Learners will develop their understanding of DC transients and of series and parallel alternating current (AC) circuits. They will consider series and parallel circuits that include resistors (R), inductors (L) and capacitors (C) in AC circuits.

The unit will also introduce learners to the theory and advantages of three-phase AC systems. This will include power measurements in a three-phase AC system and the construction and principles of operation of a three-phase AC induction motor.

Learning outcomes

On completion of this unit a learner should:

1. Be able to apply direct current (DC) circuit analysis methods and consider the types, construction and characteristics of a DC motor and generator
2. Understand the transient behaviour of resistor-capacitor (RC) and resistor-inductor (RL) DC circuits
3. Be able to apply single-phase alternating current (AC) theory
4. Be able to apply three-phase alternating current (AC) theory.

Unit content

1 Be able to apply direct current (DC) circuit analysis methods and consider the types, construction and characteristics of a DC motor and generator

Direct current (DC) circuit theorems: Thevenin's theorem eg application of theorem to a parallel circuit having two sources of electromotive force (emf) and three resistors; Norton's theorem eg application of theorem to a parallel circuit having two sources of emf and three resistors; maximum power transfer theorem eg application of theorem to a series circuit with a source of EMF, internal resistance and a load resistor; application to a more complex circuit where Thevenin needs to be applied first

Direct current (DC) motor: type eg shunt, series, compound; construction eg windings, motor starter circuits, speed control (series resistance in the armature circuit); characteristics eg EMF generated, torque, back emf, speed and power, efficiency

Direct current (DC) generator: type eg separately-excited, shunt, series compound; construction eg main frame or yolk, commutator, brushes, pole pieces, armature, field windings; characteristics eg generated voltage/field current (open circuit characteristics), terminal voltage/load current (load characteristic), $V = E - I_a R_a$

2 Understand the transient behaviour of resistor-capacitor (RC) and resistor-inductor (RL) DC circuits

Transient behaviour of RC circuit: variation of current and voltage with time when charging/discharging; time constant; graphical determination of growth and decay of voltage and current when charging/discharging; practical RC circuit to demonstrate transient behaviour; demonstrate the effect of the circuit time constant on a rectangular waveform eg integrator and differentiator circuits; calculations eg time constant, growth of capacitor voltage, initial and steady state values of current, decay of resistor voltage

Transient behaviour of RL circuit: variation of current and voltage with time when connected/disconnected to a DC voltage source; time constant; graphical determination of growth and decay of current and voltage when connected/disconnected to a DC voltage source; practical RL circuit to demonstrate transient behaviour; calculations eg time constant, growth of current, decay of induced voltage, current decay

3 Be able to apply single-phase alternating current (AC) theory

Series R, L and C alternating current (AC) circuits: current and phase angle in series combinations of RLC circuits (RL, RC, RLC); construction of phasor diagrams and relationship with voltage and impedance triangles for each of the three types of R, L and C combinations; power factor ($\cos\phi$) and power triangle eg apparent power ($S = VI$), true or active power ($P = VI\cos\phi$) and reactive power ($Q = VI\sin\phi$); conditions for series resonance eg inductive reactance equals capacitive reactance ($X_L = X_C$); Q factor (voltage magnification) eg $Q = \frac{V_L}{V}$, $Q = \frac{1}{R}\sqrt{\frac{L}{C}}$ and its importance in high and low frequency circuits

Parallel: evaluation of the voltage, current and phase angle in parallel combinations of resistance, inductance and capacitance eg RL, RC, LC and RLC; construction of phasor diagrams for impedance and phase angle; conditions for parallel resonance in an RLC circuit eg supply current and voltage in phase; impedance at resonance eg dynamic resistance $R_D = \frac{L}{CR}$; Q factor (current magnification) eg $Q = \frac{I_C}{I}$; filter circuits eg high pass, low pass, band pass, band stop

4 Be able to apply three-phase alternating current (AC) theory

Three-phase AC theory: principles of single-phase and three-phase supplies eg rotation of a single coil in a magnetic field, rotation of three identical coils fixed 120° apart in a magnetic field; star and delta methods of connection for power distribution systems; three and four wire systems; voltage relationships for star and delta connections under balanced conditions of load; calculation of power in balanced and unbalanced three-phase loads eg, $P = \sqrt{3}.V_L I_L \cos\theta$, $P = 3{I_p}^2 R_p$

Power measurements in a three-phase AC system: eg delta system – one wattmeter method, star system – two wattmeter method

Three-phase AC induction motor: construction eg stator, rotor, poles; principle of operation eg production of torque, synchronous speed, number of poles, starting methods, characteristics (speed/torque/efficiency versus current curves); concept of a rotating magnetic field eg application of a three-phase supply to the stator windings, flux generated by each phase of the stator winding

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 theorems to solve one circuit problem using Thevenin's theorem, one using Norton's theorem and one using the maximum power transfer theorem for DC networks	**M1**	analyse the effects of resonance and Q factor in both a series RLC and a parallel RLC circuit	**D1**	evaluate the need for a DC motor starter and discuss its operation
P2	explain and compare the construction and characteristics of a DC motor and a DC generator [IE4]	**M2**	discuss the advantages of power factor correction in an RLC circuit for a commercial consumer, giving a practical example by reference to specific calculations	**D2**	evaluate the performance of a three-phase induction motor by reference to electrical theory.
P3	explain the transient behaviour of current and voltage in an RC circuit and verify through calculation	**M3**	compare two different methods of power measurement in a three-phase system for both balanced and unbalanced loads.		
P4	explain the transient behaviour of current and voltage in an RL circuit and verify through calculation				
P5	use single-phase AC theory to calculate the current, voltage, impedance, power and phase angle in one of each of the series combinations of R, L and C circuits				
P6	investigate the performance of two filter circuits experimentally [IE4]				
P7	use single-phase AC theory to calculate the input current, voltage, impedance and phase angle for a parallel combination of R, L and C				

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 three-phase theory to explain the advantages of three-phase systems and star and delta methods of connection		
P9 carry out a practical power measurement on a three-phase system [SM3]		
P10 describe the construction, principle of operation and concept of a rotating magnetic field of a three-phase AC inductor motor.		

PLTS: This summary references where applicable, in the square brackets, the elements of the personal, learning and thinking skills which are embedded in the assessment of this unit. By achieving the criteria, learners will have demonstrated 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

Essential guidance for tutors

Delivery

The four learning outcomes of this unit are linked and working through them in order would be the preferred method of delivery. A combination of theory lessons and demonstrations, backed up with practical work in an electrical science laboratory/workshop will help to reinforce the new concepts and theorems. Following on from other electrical units, learners will be able to appreciate the combinations of the different components within more complex circuits/networks.

Tutors should make effective use of both paper-based and computer software-based exercises (eg calculate the required value of load resistance in a parallel circuit to obtain maximum power transfer). It is important that learners are encouraged to lay out circuits practically using either computer simulation or bread boarding techniques. Effective use of both of these methods will help to corroborate theory with practice.

Tutors may need to consider learners' level of computer skills and provide further support to enable them to use computer-based software for circuit simulation.

During delivery, learners should be given the opportunity to practise all the formulae identified in the content, but do not need to memorise them. They should, however, be encouraged to select the most appropriate and correct formula for the calculation of specific values (eg the line voltage for a star connected three-phase system $V_L = \sqrt{3}.Vp$).

The ability to transpose complex equations is a requirement of this unit and, overall, the mathematical skills required are clearly of a high level. Therefore the provision of additional learning support for mathematics may need to be considered.

To study this unit, it is essential that learners have sufficient background knowledge of electrical and electronic principles. If this is not the case then they will have difficulty with the advanced concepts covered.

Note that the use of 'eg' in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an 'eg' needs to be taught or assessed.

Outline learning plan

The outline learning plan has been included in this unit as guidance and can be used in conjunction with the programme of suggested assignments.

The outline learning plan demonstrates one way in planning the delivery and assessment of this unit.

Topic and suggested assignments/activities and/assessment
Whole-class teaching: • introduction to the unit content, scheme of work and assessment strategy • explain the idea of a constant voltage generator and demonstrate a constant voltage equivalent circuit • introduction to the use of Thevenin's theorem for solving a parallel circuit having two sources of emf and three resistors. Demonstrate the application of Thevenin's theorem to a parallel circuit to evaluate current, voltage and power. *Individual learner activity:* • tutor-led exercises on the application of Thevenin's theorem. *Whole-class teaching:* • explain the idea of a constant current generator followed by an introduction to Norton's theorem. Explain the application of Norton's theorem in the solution of parallel circuits. *Small group activity:* • tutor-led exercises on the application of Norton's theorem. *Whole-class teaching:* • explain the Maximum Power Transfer theorem followed by a demonstration to show the application to a series circuit with a source of emf, internal resistance and a load resistance. Explanation of a more complex circuit where Thevenin needs to be applied first. *Individual learner activity:* • tutor-led exercises on the application of the Maximum Power Transfer theorem. *Whole-class teaching:* • discuss the types of DC motor and the need for motor starters. Explain the construction of the different types and methods of speed control. Consider the applications for DC motors and the production of torque. *Individual learner activity:* • tutor-led solution of simple problems involving $V = E + I_a R_a$ *Whole-class teaching:* • discuss the types of DC generator, explain the construction of the different types and consider the characteristics of each. • explain the generator on load and introduce the equation $V = E - I_a R_a$ followed by evaluation of simple problems. *Practical workshop activities:* • learner investigation of the characteristics of DC motors and generators using appropriate test equipment. *Individual learner activity:* • tutor-led solution of problems involving $V = E - I_a R_a$ • plot a range of graphs for the characteristics of both generators and motors.
Prepare for and carry out **Assignment 1: DC Circuit Analysis and Generators** (P1, P2, D1).

Topic and suggested assignments/activities and/assessment
Whole-class teaching: • explain the concept of a transient response for an RC circuit, define the time constant and draw charging/discharging curves for the current and voltage then develop the equations for those curves. • explain the concept of a transient response for an RL circuit, define the time constant and draw charging/discharging curves for the current and voltage then develop the equations for those curves. *Individual learner activity:* • tutor-led solution of problems involving the calculation of current and voltage. *Whole-class teaching:* • explain the graphical determination of growth and decay of voltage and current when charging/discharging an RC circuit followed by a tutor demonstration of the effect of the circuit time constant or Integrator and Differentiator circuits • explain the graphical determination of growth and decay of voltage and current when charging/discharging an RL current. • demonstration to show the transient behaviour when charging/discharging both an RC and an RL circuit. *Individual learner activity:* • tutor-led solution of problems on the graphical determination of growth and decay in RC and RL circuits. • comparison of practical transient behaviour with theory.
Prepare for and carry out **Assignment 2: DC Transients** (P3, P4).
Whole-class teaching: • revise the method of evaluating capacitive and inductive reactance followed by a demonstration to show the calculation of impedance, current and phase angle for series AC circuits • explain the construction of phasor diagrams and the relationship with voltage and impedance triangles • demonstrate of the calculation of power and power factor in AC circuits *Individual learner activities:* • tutor-led solution of problems on series AC circuits and involving power and power factor in AC circuits. *Whole-class teaching:* • explain and discuss the conditions for resonance in R, L and C circuits, define Q factor and its importance in high and low frequency circuits. • demonstrate the effects of series resonance using circuit simulation software *Individual learner activity:* • tutor-led solution of problems involving resonance in series AC circuits. *Practical workshop activities:* • small group learner activity to derive phasor diagrams from voltage measurements taken from combinations of series R, L and C circuits. Learners to then compare practical and theoretical results. *Whole-class teaching:* • explain the method of evaluation of voltage, current and phase angle for parallel combinations of R, L and C. • explain the construction of phasor diagrams to evaluate impedance and phase angle for a parallel circuit • explain the conditions for parallel resonance and introduce the method for the evaluation of dynamic resistance (impedance), Q factor, voltage and current.

Topic and suggested assignments/activities and/assessment
Individual learner activities: • tutor-led solution of problems on parallel AC circuits and involving parallel resonance. *Practical workshop activities:* • learners to compare practical and theoretical results of single phase parallel circuits including power factor correction.
Prepare for and carry out **Assignment 3: AC Single-phase Series and Parallel Circuits** (P5, P7, M1, M2).
Whole-class teaching: • explain the operation of filter circuits including low pass, high pass, band pass and band stop.
Prepare for and carry out **Assignment 4: Filter Circuits** (P6).
Whole-class teaching: • explain the voltage and current relationships in a three-phase AC system for star and delta connections. Tutor-led demonstration of the construction of phasor diagrams for the two methods of connection and the calculation of power in balanced and unbalanced three-phase loads. *Individual learner activity:* • tutor-led solution of problems involving the calculation of power in balanced and unbalanced three-phase loads. *Practical workshop activities:* • learners carry out three-phase power measurements using different wattmeter arrangements. Learners then compare practical measurements with those evaluated theoretically.
Prepare for and carry out **Assignment 5: Three-phase AC Theory** (P8, P9, M3).
Whole-class teaching: • explain the concept of a rotating field, construction and principle of operation, production of torque, synchronous speed, number of poles and starting methods relevant to a three-phase induction motor. *Individual learner activity:* • tutor-led solution of simple problems on synchronous speed and the calculation of torque. *Practical workshop activities:* • learners make measurements of speed, torque, efficiency and current for three-phase induction motors. Learners to then plot graphs and compare practical and theoretical results.
Prepare for and carry out **Assignment 6: Three-phase AC Induction Motor** (P10, D2).
Feedback on all assessment tasks, unit evaluation and close.

Assessment

A good deal of the assessment evidence for this unit can be achieved by practical experimentation, with real components and circuits and/or computer-based software packages where appropriate.

Because of the nature of the learning outcomes and unit content, up to six assessment instruments may be required. If a structured programme of practical work and short tests is also used then the actual total number of pieces of assessed work could be even more than this. However, careful consideration should be given when designing the assessment not to place an unduly high assessment burden on learners or the tutor. Wherever possible, practical work should lead to a final product that can be assessed without further need for report writing.

Practical activities within the laboratory will need careful supervision. Tutors can capture this evidence by using appropriate records of observation and oral questioning for each learner.

For P1 learners will need to be able to solve circuits involving Thevenin's theorem, Norton's theorem and the maximum power transfer theorem. Before attempting this criterion, learners could be introduced to the idea of a constant voltage source and a constant current source by using a suitable practical demonstration. Further development of this could lead to the link between Thevenin and Norton and then on to the use of Thevenin, before applying the maximum power transfer theorem.

P2 involves the explanation and comparison of a motor and a generator. Learners could possibly be shown actual motors/generators and be issued with incomplete diagrams for completion and annotation.

P3 and P4 require learners to explain the transient behaviour of current and voltage in an RC and an RL circuit both practically and theoretically. Use of a simple bread-boarding technique for both criteria would be ideal here.

For both P5 and P7, an in-class assessment involving the evaluation of current, voltage, impedance and phase angle could be utilised. Learners could be given different circuit values and be encouraged to check their answers with a suitable software programme.

The investigation of the performance of two filter circuits (P6) could be achieved by using a signal generator with a low voltage output ($V_{IN} = IV$)connected to an RC network. Learners could then measure the output (V_{OUT}) as the frequency is raised from, for example, 100Hz to 10,000 Hz.

P8 requires learners to explain the advantages of three-phase systems (eg smaller conductors, two available voltages). The latter of these leads into the two forms of connection (star and delta). Assessment could take the form of an incomplete handout to be submitted at the end of a lecture or film about the advantages and forms of connection.

P9 requires learners to carry out practical power measurements in three-phase systems. A suitable three-phase resistance load bank together with a three-phase, four wire low voltage supply and three wattmeters could be used to enable learners to measure the power using 1, 2 and 3 wattmeters for the different configurations.

Evidence for P10 is likely to be in the form of an investigative report. Again, it may be helpful to provide learners with an incomplete diagram for them to complete and annotate. For the principles of operation and concept of a rotating magnetic field of a three-phase induction motor it may be necessary to include a number of key words (eg synchronous speed, pairs of poles) and point to one specific type of three-phase induction motor (eg squirrel-cage rotor).

The analysis of the effects of resonance and Q factor in both a series RLC and a parallel RLC circuit (M1) builds on and could be linked to P5 and P7. Evidence for M1 could also be provided by considering the difference in resonance frequency, for example when the value of the resistance is varied.

For M2, learners need to discuss the advantages of power factor correction in an RLC circuit for a commercial consumer, giving a practical example by reference to specific calculations. These could include reduced cost to the consumer with reference to a practical example. This could follow a practical demonstration of how the supply current reduces on the introduction of power factor correction, but can increase if over-corrected. M3 could be linked to the practical carried out for P9.

All except the smallest of motors require some type of starter to prevent heavy currents being drawn from the supply on starting. D1 is intended to evaluate this requirement in detail and consider the need for a DC motor starter (eg DC faceplate starter) and to discuss its operation. It is expected that learners will draw from the work done at pass and merit and produce a referenced technical report, supported by a suitably labelled diagram to aid their discussion of the operation.

D2 requires learners to evaluate the performance of a three-phase induction motor by reference to electrical theory, eg squirrel cage by reference to electrical theory. This could be achieved practically by using appropriate experimental rigs that allow the learner to compare their results with the known characteristics for specific machines.

Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Edexcel assignments to meet local needs and resources.

Criteria covered	Assignment title	Scenario	Assessment method
P1, P2, D1	DC Circuit Analysis and Generators	An activity requiring learners to complete three tasks that together solve circuit problems, compare a DC motor and generator, and evaluate the performance of a three-phase induction motor.	A report containing solutions to circuit theorems and written responses about DC motor/generator and three-phase induction motor characteristics. Carried out under controlled conditions.
P3, P4	DC Transients	A written activity that requires learners to explain the transient behaviour of an RC and RL circuit with a numerical verification.	A report containing written responses about the transient behaviour of RC/RL circuits supported by numerical calculations carried out under controlled conditions.
P5, P7, M1, M2	AC Single-phase Series and Parallel Circuits	A written activity requiring learners to carry out calculations relating to the behaviour of series and parallel R, L and C single phase AC circuits.	A report containing the results of calculations to determine specific parameters of series and parallel R, L and C single phase AC circuits carried out under controlled conditions.
P6	Filter Circuits	A practical investigation for learners to measure the response of two simple filter circuits.	A report containing written responses and graphical evidence regarding the response of simple filter circuits.
P8, P9, M3	Three-phase AC Theory	A combined written and practical activity requiring learners to explain the advantages of three-phase systems, the star and delta method of connection followed by a practical power measurement with a comparison of two different methods for both balanced and unbalanced loads.	A report containing written responses to the advantages of three-phase systems, an illustration of the methods of connection and measurements of the practical work carried out.

Criteria covered	Assignment title	Scenario	Assessment method
P10, D2	Three-phase AC Induction Motor	A written activity describing the construction, operation and concept of a rotating magnetic field for a three-phase (AC) induction motor together with an evaluation of its performance.	A report containing neat diagrams and descriptions relating to a three-phase (AC) induction motor.

Links to National Occupational Standards, other BTEC units, other BTEC qualifications and other relevant units and qualifications

This unit forms part of the BTEC Engineering sector suite. This unit has particular links with:

Level 1	Level 2	Level 3
		Electrical and Electronic Principles
		Mathematics for Engineering Technicians
		Further Mathematics for Engineering Technicians
		Three-phase Systems

The unit also covers some of the knowledge and understanding associated with the SEMTA Level 3 National Occupational Standards in Electrical and Electronic Engineering, particularly:

- Unit 15: Checking the Compliance of Electronic Components Against the Specification
- Unit 17: Assembling and Wiring Electronic Equipment and Systems
- Unit 18: Testing Post-Production Electronic Components and Circuits
- Unit 21: Writing Specifications for Testing Electronic Components or Circuits
- Unit 24: Assembling Transformers and Inductors
- Unit 25: Fitting Small Transformer and Inductor Cores
- Unit 26: Assembling Rotor and Armature Windings
- Unit 27: Assembling Stator Windings
- Unit 28: Assembling and Fitting Commutators
- Unit 30: Assembling and Fitting Electrical Rotating Equipment
- Unit 31: Mounting Electrical Components in Enclosures
- Unit 32: Wiring Electrical Components and Equipment in Enclosures
- Unit 33: Selecting and Preparing Materials and Components for Electrical Assembly
- Unit 34: Carrying Out Functional Tests on Electrical Equipment.

Essential resources

Learners will need access to a well equipped electrical/electronics laboratory with up to date instruments such as digital/analogue multimeters, function generators and oscilloscopes. Centres will also need to provide appropriate circuit components as identified in the unit content together with the means to physically construct circuits.

Centres are strongly advised to consider the provision of suitable hardware and software to enable the use of computer-based methods for circuit design and simulation.

Employer engagement and vocational contexts

Centres are encouraged to relate theory to real engineering applications wherever possible. Industrial visits or work experience, where appropriate, would be of value and can give learners an appreciation of the industrial applications of further electrical and electronic principles.

Much of the work for this unit can be set in the context of learners' work placements or be based on case studies of local employers. Further information on employer engagement is available from the organisations listed below:

- Work Experience/Workplace learning frameworks – Centre for Education and Industry (CEI – University of Warwick) – www.warwick.ac.uk/wie/cei/
- Learning and Skills Network – www.vocationallearning.org.uk
- Network for Science, Technology, Engineering and Maths Network Ambassadors Scheme – www.stemnet.org.uk
- National Education and Business Partnership Network – www.nebpn.org
- Local, regional Business links – www.businesslink.gov.uk
- Work-based learning guidance – www.aimhighersw.ac.uk/wbl.htm

Indicative reading for learners

Textbooks

Bird J O – *Electrical and Electronic Principles and Technology* (Newnes, 2007) ISBN 9780750685566

Bird J O – *Electrical Circuit Theory and Technology* (Newnes, 2007) ISBN 9780750681391

Robertson C R – *Further Electrical and Electronic Principles* (Newnes, 2008) ISBN 0750687479

Delivery of personal, learning and thinking skills (PLTS)

The following table identifies the PLTS that have been included within the assessment criteria of this unit:

Skill	When learners are …
Independent enquirers	analysing and evaluating information when comparing a DC motor and generator, and investigating filter circuits
Self-managers	organising their time and resources and prioritising actions when using measuring equipment.

Although PLTS are identified within this unit as an inherent part of the assessment criteria, there are further opportunities to develop a range of PLTS through various approaches to teaching and learning.

Skill	When learners are …
Creative thinkers	trying different theorems to solve DC circuit problems
Reflective learners	reviewing progress when solving problems during the learner's activities and acting on the outcomes to make corrections to understanding solutions
Team workers	collaborating with others when working on practical and investigative group work to achieve a valid solution.

Functional skills – Level 2

Skill	When learners are …
ICT – Use ICT systems	
Select, interact with and use ICT systems independently for a complex task to meet a variety of needs	using circuit simulation software to evaluate data when solving electrical principles problems
Mathematics	
Understand routine and non-routine problems in a wide range of familiar and unfamiliar contexts and situations	solving routine electrical principles problems set within electrical engineering contexts and situations
Identify the situation or problem and the mathematical methods needed to tackle it	recognising the relevant parameters and formulae to be applied to given electrical engineering situations
Select and apply a range of skills to find solutions	selecting and applying formulae to solve electrical engineering problems
Use appropriate checking procedures and evaluate their effectiveness at each stage	checking the results of solutions to electrical principles problems to evaluate their effectiveness and reality at each stage of the calculation
English	
Speaking and listening – make a range of contributions to discussions and make effective presentations in a wide range of contexts	speaking with and listening to peers and tutors to establish an understanding of electrical principles concepts and ideas
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	selecting, reading and using appropriate electrical principles information data sources to solve problems and carry out practical work
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	taking notes and solving electrical principles problems to communicate accurate solutions effectively.