Unit 39: Electrical Principles in Building Services Engineering

NQF Level 3: BTEC National

Guided learning hours: 60

Unit abstract

The use of electricity is an essential part of life in the modern world. Electricity provides us with the means to energise many devices, systems and processes that are part of our technological environment. Electricity, in combination with these technologies, is used to transfer energy, to provide mechanisms for control and to transmit information in a variety of forms.

Basic electrical theories need to be understood and considered by all those involved in the design or installation of plant, equipment, machinery, control systems or the electrical circuitry that is required to power both mechanical and electrical services within buildings. In this unit learners will gain essential underpinning knowledge through study of the form and function of electrical devices, and by investigating the various ways to transfer, modify, transform, and control electrical energy.

Learners will be able to distinguish between the requirement for single and three-phase circuits, and will develop a basic understanding of fundamentals such as the difference between analogue and digital signals, and the relevance of these to control systems.

Learning outcomes

On completion of this unit a learner should:

1 Be able to apply appropriate units, measures and devices in determining and describing quantities of electrical energy

2 Understand basic electrical quantities and how the use and behaviour of simple electrical components affects these quantities and use circuit theorems to determine such quantities

3 Be able to solve problems relating to the use of single-phase and three-phase circuits and undertake simple circuit design projects to meet a specification

4 Understand the principles of transformers and rotating machines and demonstrate practical applications in industry.

Unit content

1 **Be able to apply appropriate units, measures and devices in determining and describing quantities of electrical energy**

Units: understanding the basic electrical quantities and SI units and the relevant symbols; mass; time; length; luminous intensity; electric current; thermodynamic temperature; amount of substance; using derived SI units, combinations of basic units and multiplication of units

Calculations: using the unit of charge (the coulomb), unit of power, unit of work or energy, unit of force, units of electrical resistance and conductance, electrical potential and electromotive force (EMF, to calculate electrical power and energy, electrical charge and quantity of energy. Use of Ohm's law to include multiples and sub-multiples of units

Instruments: use of electrical measuring instruments, eg ammeter, voltmeter, Ohmmeter, multimeter, cathode ray oscilloscope (CRO)

2 **Understand basic electrical quantities and how the use and behaviour of simple electrical components affects these quantities and use circuit theorems to determine such quantities**

Electric current: fundamentals of electrical systems and sub-systems; use of conductors and insulators; quantity of electricity in electric current; potential difference and voltage; direct current (DC); alternating currents and voltages (AC), including where appropriately used; ac values; basic waveforms; magnetic; chemical and heating effect of currents, use of fuses, electrical resistance including the effects of variation in this

Circuit theorems: Thevenin's theorem; Norton's theorem; superposition theorem; maximum power transfer theorem; Faradays Law; Lenz's Law; Kirchhoff's laws

Electrical components: resistors; colour coding and Ohmic values, letter and digit codes; capacitors and capacitance; electrostatic field; electric field strength; inductors; calculation of stored energy; features and inductance of a coil; half and full wave rectifiers; simple semiconductors

Applications: an appreciation of why AC is used in preference to DC; principles of the AC generator; AC voltage transformation and transmission

3 **Be able to solve problems relating to the use of single-phase and three-phase circuits and undertake simple circuit design projects to meet a specification**

Single-phase circuits: phasor diagrams and current and voltage waveforms; purely resistive ac circuits; purely inductive ac circuits; purely capacitive ac circuits; drawing circuit diagrams; conditions for resonance; frequency selectivity: Q-factor (effects and typical values); impedance and reactance (for series and parallel circuits); power and power factor; benefits of power factor correction

Three-phase circuits: components of three phase circuit; phasor diagrams for a balanced, delta connected load; applications in use; star connection, including phasor diagrams, neutral point/star point and relationship to single-phase supply; relationships and comparisons between star and delta connected loads; power dissipated; apparent power; measurements of power and apparent power; advantages of three-phase systems

4 **Understand the principles of transformers and rotating machines and demonstrate practical applications in industry**

Transformers: principle operation of single-phase transformer; rating of a transformer; construction of a transformer for power, audio frequency and radio frequency; calculations to specify transformers; transformer no-load phasor diagram; transformer on-load phasor diagram; electromagnetic induction, equivalent circuit of a transformer; regulation, losses (iron, copper, other) and efficiency of a transformer; three-phase transformers; current and voltage transformers and their uses

Rotating machines: role of the electrical machine; AC motor principles (Induction and synchronous); energy conversion process in a machine, DC machines (series and shunt types); construction of machines; function of machines and generators; action of a commutator; armature reaction; speed/torque; starter control; typical applications; characteristics, enclosures for motors; inverter control

Grading grid

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all of the learning outcomes for the unit. The 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 calculate quantities of electrical power, current, charge and energy using a range of single and multiple SI units	M1 solve a range of problems involving AC and DC electric circuits and electromagnetic induction by the use of Ohm's, Faraday's and Lenz's Laws	D1 analyse the importance of correctly specifying and selecting building services plant and equipment in regard to single- and three-phase requirements and explain why with examples
P2 demonstrate how equipment, instruments and devices are used in the measurement of electricity and describe their functions and uses	M2 produce clear and accurate answers to calculations using Thevenin's, Norton's, Kirchhoff's superposition and maximum power theorems for both alternating and direct current networks	D2 evaluate the types of motors commonly available to the market place and used in building services applications and compare the advantages and disadvantages in use.
P3 define and compare the operational characteristics and applications of alternating and direct current networks and describe their component parts	M3 produce clear and accurate solutions to a variety of practical problems related to single- and three-phase circuits	

continued...

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:**
P4 describe and illustrate the characteristics and applications of the various configurations of single- and three-phase circuits and determine the main parameters within these circuits P5 explain and illustrate the operating principles, features, functions and everyday application of transformers and the various types of simple DC and AC electrical machine and rotating motor P6 understand the use, construction and different types of phasor diagrams for a range of single and three phase transformers.	M4 make valid and appropriate decisions relating to the selection and specification of transformers and motors for building engineering services applications.	

Essential guidance for tutors

Delivery

Tutors delivering this unit have opportunities to use a wide range of techniques. Lectures, discussions, seminar presentations, site visits, supervised practicals, research using the internet and/or library resources and the use of personal and/or industrial experience are all suitable. Delivery should stimulate, motivate, educate and enthuse learners. Visiting expert speakers could add to the relevance of the subject.

This unit should be used primarily as a stand-alone unit as it deals with the fundamental principle of electricity. It could also be used as a building block or integrated with other units in building engineering services, engineering. Care should be taken to avoid duplication of subject matter and assessments when integrating delivery.

It is important to ensure that learners studying this unit are aware of the planned and progressive structure that exists throughout the learning outcomes. The emphasis being that before the next step in the learning process can usually be taken, the knowledge from the previous learning outcome is required to underpin the next. However, there may be incidents where learners may have gained adequate knowledge and experience before attempting a new learning outcome but this should be adequately proven through a logical assessment process.

Learners should clearly appreciate that each aspect and topic forms a stage in the overall process of understanding the principle of how electricity works and its application and relevance to plant, equipment and machinery that is used both in the electrical and building engineering services industry. The unit does not deal with the actual installation of electrical plant and equipment, which is handled in the units Electrical Installations A and B.

The unit should not be seen by learners as an academic exercise. It should, at all times, be based on real-life applications and reflect industry best practice. The method of delivery should, as far as possible, be activity based where learning activities could include the use of laboratory work, case studies, product investigation and completion of basic design proposals and specifications.

The delivery process should provide a balance between the calculations implicit within learning outcome 1, the knowledge and understanding required in learning outcomes 2 and 3 and the creativity and application required of learning outcome 4. These should also, where possible, ensure that appropriate attention is given to health, safety and welfare arrangements.

Learners should be encouraged to actively refer to documents, such as IEE Regulations, CIBSE Guides, codes of practice, British Standards and building regulations in order to gain a wide and confirmed range of advice on best practices for information on electrical plant, machinery and electrical circuits.

The use of current, up-to-date manufacturers' product information is also encouraged to help learners apply the principles and procedures that would be used in industry. Emphasis should be made of the need for learners to understand how to correctly access and use particular charts and diagrams which aid manual calculations to be carried out. Industry standard software may be used to perform certain design functions in the process of assembling a project. It is important that learners are able to challenge any results gained from the software by carrying out either rule-of-thumb or long-hand manual calculations.

There is an assumption that learners have appropriate levels of mathematical, science and IT skills to undertake and complete this unit.

Group activities are permissible, but tutors will need to ensure that individual learners are provided with equal experiential and assessment opportunities.

Health, safety and welfare issues are paramount and should be strictly reinforced through close supervision of all workshops and activity areas, and risk assessments must be undertaken prior to practical activities. Centres are advised to read the *Delivery approach* section on page 24, and *Annexe G: Provision and Use of Work Equipment Regulations 1998 (PUWER)*.

Assessment

Evidence for this unit may be gathered from a variety of sources, including well-planned investigative assignments, case studies or reports of practical assignments.

There are many suitable forms of assessment that could be employed, and tutors are encouraged to consider and adopt these where appropriate. Some examples of possible assessment approaches are suggested below. However, these are not intended to be prescriptive or restrictive, and are provided as an illustration of the alternative forms of assessment evidence that would be acceptable. General guidance on the design of suitable assignments is available on page 19 of this specification.

Some criteria can be assessed directly by the tutor during practical activities. If this approach is used then suitable evidence would be observation records or witness statements. Guidance on the use of these is provided on the Edexcel website.

This unit allows for flexibility in the various types of assessment methods that can be used throughout the learning outcomes. Some criteria are best suited for either well-planned laboratory work, others as assignments that involve the inclusion of calculations, diagrams and text, or as simple design activities involving the selection and specification processes. Few criteria will be suitable for the adoption of all three methods of assessment but some they may allow two. The unit does not lend itself fully to a project-work approach to assessment.

The fundamental principles of electrical operations are often best demonstrated when they are physically witnessed and learners are able to see for themselves the effects and results. Experiments in a laboratory, showing different processes and uses of equipment could be undertaken by learners, with evidence for assessment presented as a combination of a visual record by the assessor and the preparation and maintenance of suitable learner logbooks. Learners could also provide work-based evidence for assessment, provided that this evidence is appropriate and authenticated as the learner's own work.

To achieve a pass grade learners must meet the six pass criteria listed in the grading grid.

For P1, learners must calculate quantities of electrical power, current, charge and energy using a range of single and multiple SI units. They are expected to perform calculations to formulate answers to simple problems involving electrical power, current, charge and energy or any combination of the same. Using general knowledge and research skills they should show how these units are applied and recognised in the everyday world.

For P2, learners must demonstrate how equipment, instruments and devices are used in the measurement of electricity and describe their functions and uses. They should describe portable instruments as used for testing and certificating or those instruments that may be fixed into an installation for permanent measuring/monitoring/recording of the system. Learners will also need to describe and illustrate the function, features, operations and contextualised use of each of the instruments.

For P3, learners must define the operational characteristics and applications of alternating and direct current networks and describe their component parts. They should explore and describe where these currents can be appropriately used in the everyday world in general and the building engineering services industry in particular. Learners are also expected to communicate how each current is effectively derived and the operational features, values, wave forms, magnetic and chemical effects, advantages and disadvantages etc. This should include descriptions and illustrations of all the necessary components that would be required to enable a current to be created and safely operated. Correct terminology should be used throughout.

For P4, learners must describe and illustrate the characteristics and applications of the various configurations of single- and three-phase circuits and determine the main parameters within these circuits. They should demonstrate an understanding of the difference in characteristics of the two types of circuits, and why and where they are used in the building engineering services industry. Correct terminology should be used throughout. Learners are also expected to determine the main parameters within simple AC single- and three-phase circuits eg conditions of resonance, selectivity, Q factor, impedance and reactance and power factor.

For P5, learners must explain and illustrate the operating principles, features, functions and everyday application of transformers and the various types of simple DC and AC electrical machine and rotating motor, such as those in fans and pumps. They should employ the correct terminology and use their investigative skills to explore where transformers and rotating machines can be appropriately used in the everyday world and the building engineering services industry and describing these in simple terms.

For P6, learners are expected to understand the uses, construction and different types of phasor diagrams for a range of single and three phase transformers. They should describe the role of these machines and the different characteristics of a range of types. Learners should determine how the machines are constructed, the materials that are typically used in the construction and prepare simple sketches to demonstrate their knowledge of each machine.

To achieve a merit grade learners must meet all of the pass grade criteria **and** the four merit grade criteria.

For M1, learners must solve a range of problems involving AC and DC electric circuits and electromagnetic induction by the use of Ohm's, Faraday's and Lenz's Laws. This could be an extension of the work carried out in P2 and P3. Learners are expected to produce clear and accurate answers showing an understanding of the relevant application of the three different Laws. They should show their statements and meanings and how they relate to electromagnetic induction, inductors and stored energy. Exact and correct electrical terminology must be used in all the answers to the problems, together with accurate sketches and/or diagrams where appropriate.

For M2, learners must produce clear and accurate answers to calculations using Thevenin's, Norton's, Kirchhoff's superposition and maximum power theorems for both alternating and direct current networks. They should apply each of the theorems to a range of problems and produce clear and accurate answers to determine the currents flowing with the differing effect of each theory.

For M3, learners must produce clear and accurate solutions to a variety of practical problems related to single- and three-phase circuits. They should show understanding of delta and star connections in three-phase circuits and when to correctly apply them in given solutions. Learners are required to draw a complete phasor diagram for a balance, star and delta connected loads. They should describe fully the advantage and disadvantages of single- and three-phase systems relevant to building engineering service solutions. This could be a natural extension of the work developed for P4. Correct terminology must be used throughout.

For M4, learners must make valid and appropriate decisions relating to the selection and specification of transformers and motors for building engineering services applications. Learners should describe with the aid of sketches and schematic drawings, where and how this equipment can/or should be suitably applied. In making decisions, learners are expected to extract appropriate data from drawings, reports and calculations, use this data alongside manufacturers' information to write specifications and select and produce schedules transformers and rotating machines. Learners should show that the information they have gathered is current and determine the advantages over previous technologies for the same equipment.

To achieve a distinction grade learners must meet all of the pass and merit grade criteria **and** the two distinction grade criteria.

For D1, learners must analyse the importance of correctly specifying and selecting building services plant and equipment in regard to single and three phase requirements, and explain why with examples. They should show their understanding of the different type of plant and equipment that demand the alternative electrical connections and the significant implications that a wrong specification can have on a project. Learners are expected to justify their explanations of the important reasons by citing examples of problems that may/could have occurred in practice and how these could be resolved.

For D2, learners must evaluate the types of motors commonly available to the market place and used in building services applications and compare the advantages and disadvantages in use. They should prepare a professional report on the products to

include the use of photographs, diagrams and sketches. Learners are required to use their analytical skills to compare the advantages and disadvantages of the motors selected and their judgemental skills to explain all the implications of using the correct and incorrect machines in particular applications.

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

The learning outcomes in this unit are closely linked with, for example, *Unit 40: Electrical Installations Standards and Components in Building Services Engineering, Unit 41: Electrical Installations Design in Building Services Engineering* and *Unit 42: Commissioning Electrical Installations in Building Services Engineering*, together with similar units at Higher National and degree level.

This unit may have links to the Edexcel Level 3 Technical and Professional NVQs for Construction and the Built Environment. Updated information on this, and a summary mapping of the unit to the CIC Occupational Standards, is available from Edexcel. See *Annexe D: National Occupational Standards/mapping with NVQs.*

This unit presents opportunities to demonstrate key skills in application of number, communication, information and communication technology, improving own learning and performance, problem solving and working with others. Opportunities for satisfying requirements for Wider Curriculum Mapping are summarised in *Annexe F: Wider curriculum mapping.*

Essential resources

Centres should have access to a wide range of hard copy or online technical and manufacturers' literature, some of which are listed below.

The availability of visual aids such as the range of basic electrical components indicated in learning outcomes 2 and 4 would be advantageous. These can be either in the form of models and/or as part of live installations.

Centres should have access to sets of electrical schematic drawings to support the learning process and to facilitate assessments. Where these drawings are used as part of the assessment process it is recommended that repeated use of the same type is avoided to maintain the freshness of the assessment process.

Learners should be given access to laboratories that allow the application of electrical principles to be put into practice. Learners could witness this or take part in experiments to see how electrical terminology is expressed in real terms, to solve given problems and achieve basic designs of simple circuits to operate small pieces of plant and equipment.

Indicative reading for learners

Textbooks

Bell F and Whitehead R — *Basic Electrical and Electronic Engineering, 4th Edition* (Blackwell Science, 1993) ISBN 0632034939

Bird J — *Electrical and Electronic Principles and Technology, 2nd Edition* (Newnes, 2004) ISBN 0750665505

Hiley J, Brown K and Smith I — *Electrical and Electronic Technology, 9th Edition* (Prentice Hall, 2004) ISBN 0131143972

Robertson C — *Fundamental Electrical and Electronic Principles, 2nd Edition* (Elsevier, 2001) ISBN 0750651458

Key skills

Achievement of key skills is not a requirement of this qualification but it is encouraged. Suggestions of opportunities for the generation of Level 3 key skill evidence are given here. Tutors should check that learners have produced all the evidence required by part B of the key skills specifications when assessing this evidence. Learners may need to develop additional evidence elsewhere to fully meet the requirements of the key skills specifications.

Application of number Level 3	
When learners are:	**They should be able to develop the following key skills evidence:**
• calculating quantities of electrical power, current, charge and energy using a range of single and multiple SI units.	N3.1 Plan an activity and get relevant information from relevant sources. N3.2 Use this information to carry out multi-stage calculations to do with: a amounts or sizes b scales or proportion c handling statistics d using formulae. N3.3 Interpret the results of your calculations, present your findings and justify your methods.
Communication Level 3	
When learners are:	**They should be able to develop the following key skills evidence:**
• defining the operational characteristics and applications of alternating and direct current networks and describe their component parts.	C3.1a Take part in a group discussion. C3.1b Make a formal presentation of at least eight minutes using an image or other support material. C3.2 Read and synthesise information from at least **two** documents about the same subject. Each document must be a minimum of 1000 words long. C3.3 Write **two** different types of documents, each one giving different information about complex subjects. One document must be at least 1000 words long.

Information and communication technology Level 3	
When learners are:	**They should be able to develop the following key skills evidence:**
• describing and illustrating the characteristics and applications of the various configurations of single- and three-phase circuits and determining the main parameters within these circuits.	ICT3.1 Search for information, using different sources, and multiple search criteria in at least one case. ICT3.2 Enter and develop the information and derive new information. ICT3.3 Present combined information such as text with image, text with number, image with number.
Improving own learning and performance Level 3	
When learners are:	**They should be able to develop the following key skills evidence:**
• demonstrating how equipment, instruments and devices are used in the measurement of electricity and describing their functions and uses.	LP3.1 Set targets using information from appropriate people and plan how these will be met. LP3.2 Take responsibility for your learning, using your plan to help meet targets and improve your performance. LP3.3 Review progress and establish evidence of your achievements.
Problem solving Level 3	
When learners are:	**They should be able to develop the following key skills evidence:**
• producing clear and accurate solutions to a variety of practical problems related to single- and three-phase circuits.	PS3.1 Explore a problem and identify different ways of tackling it. PS3.2 Plan and implement at least one way of solving the problem. PS3.3 Check if the problem has been solved and review your approach to problem solving.

Working with others Level 3	
When learners are:	**They should be able to develop the following key skills evidence:**
• demonstrating how equipment, instruments and devices are used in the measurement of electricity and describing their functions and uses.	WO3.1 Plan work with others. WO3.2 Seek to develop co-operation and check progress towards your agreed objectives. WO3.3 Review work with others and agree ways of improving collaborative work in the future.