Unit 319E: Understand advanced electrical science and principles

# Delivery guide

Unit information

This unit is designed to enable learners to understand the relationship between electrical scientific principles and the competencies required of a qualified electrical operative. Its content covers the knowledge and understanding required to underpin the application of skills in the installation of electrical systems and equipment.

Learners may be introduced to this unit by asking themselves questions such as:

* What are the renewable sources of electricity relevant to my trade?
* What is the application of transformers and electrical motors?
* What are the types of luminaires that I may install?
* What are the types of electrical heating that I may work with?
* What are the types of electronic components used in electrical systems?

Learning outcomes

1. Understand renewable and other sources of electricity
2. Understand the properties of electrical circuits and components
3. Understand the operating principles and applications of DC machines and AC motors
4. Understand the principles and applications of electrical lighting systems
5. Understand the principles and applications of electrical heating systems
6. Know the types, applications and limitations of electronic components in electrical systems and equipment

Suggested resources

Textbooks

* Tanner, P. (2018) *The City & Guilds Textbook: Book 1 Electrical Installations for the Level 3 Apprenticeship (5357), Level 2 Technical Certificate (8202) & Level 2 Diploma (2365).* London: Hodder Education.

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* Tanner, P. (2018) *The City & Guilds Textbook: Book 2 Electrical Installations for the Level 3 Apprenticeship (5357), Level 3 Advanced Technical Diploma (8202) & Level 3 Diploma (2365)*. London: Hodder Education.

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Websites

* [BBC Bitesize | Homepage](https://www.bbc.co.uk/bitesize)
* [Learning Lounge | Homepage](https://www.learninglounge.com/)
* [SmartScreen | Homepage](https://www.smartscreen.co.uk/)
* [Wikipedia | Homepage](https://en.wikipedia.org/wiki/Main_Page)
* [YouTube | GSH Electrical](https://www.youtube.com/channel/UCgtbE9w_d-u2AvPp3WBlPfQ)
* [YouTube | Completely Electrical’s STEM show](https://www.youtube.com/channel/UCxD2iCtcl_8IeWs6d-W-E6g)
* [YouTube | How do smart meters work – Which? advice](https://www.youtube.com/watch?v=f_a3c_EbCSo)
* [YouTube | How does an Induction Motor work?](https://www.bing.com/videos/search?q=How+does+an+Induction+Motor+work+%3f+-+YouTube&&view=detail&mid=1B1B31835F70A8EEDA5D1B1B31835F70A8EEDA5D&&FORM=VRDGAR&ru=%2Fvideos%2Fsearch%3Fq%3DHow%2Bdoes%2Ban%2BInduction%2BMotor%2Bwork%2B%253f%2B-%2BYouTube%26qpvt%3DHow%2Bdoes%2Ban%2BInduction%2BMotor%2Bwork%2B%253f%2B-%2BYouTube%26FORM%3DVDRE)

| **Learning outcomes** | **Criteria** | **Delivery guidance** |
| --- | --- | --- |
| 1. Understand renewable and other sources of electricity | * 1. The basic operating principles of renewable sources of electricity | * Learners to recognise the basic operating principles of renewable sources of energy, including: * solar thermal for supplying hot water by using energy from the sun * solar PV for supplying electrical energy by using energy from the sun * geothermal for power generation and heating/cooling by using the earth’s natural temperature * wind for generating electrical energy by rotating generator blades * ocean energy such as wave and tidal energy by harnessing the power of the sea * micro-hydro for generating electricity from waterways. |
| * 1. The basic operating principles of combined heat and power (CHP) including micro-CHP | * Learners to understand the basic operating principles of combined heat and power (CHP), and micro-CHP, such as the simultaneous production of electricity and useful thermal energy from a single source. * Learners to understand that the energy source for CHP can be fossil fuels or renewable energy. * Learners to understand that the CHP concept can be large scale for industry or small scale (micro-CHP) for residential buildings. |
| * 1. The basic operating principles of other sources  of electricity | * Learners to understand that electricity can be produced from cells and batteries (chemical effect of an electric current to produce direct current (DC)). * Learners to understand that a back-up system of uninterruptable power supply (UPS), where installed, can automatically switch in should a power failure occur in the primary system. |
| * 1. Smart metering | * Learners to understand: * that smart metering is replacing conventional energy meters for electricity and gas * that smart metering can measure how much gas and electricity is being used and display the results on a home display * that smart metering removes the need for estimated bills * the limitations of first-generation smart meters turning ‘dumb’ when switching suppliers until a software update can be performed * that poor signal may prevent the smart meter from working. * Learners to be shown an example of smart meters and how they work (see YouTube video in Suggested resources). |
| 1. Understand the properties  of electrical circuits and components | * 1. The appropriate mathematical principles which are relevant to electrical work tasks | * Learners to apply and perform mathematical principles appropriate to electrical work, such as: * indices (to the power of 10) * transposition of basic formulae * right-angled triangles and Pythagoras’ theorem (trigonometry) * statistics. * Learners to be familiar with the worked examples of these principles in Tanner, *Book 1* and BBC Bitesize. |
| * 1. Quantities relevant to electrical work | * Learners to understand the quantities relevant to electrical work: * impedance (Z) measured in ohms * inductance (L) measured in henrys * inductive reactance (XL) measured in ohms * capacitive reactance (XC) measured in ohms * capacitance (C) measured in farads * power factor (pf) – no units as it is a ratio. |
| * 1. The relationship between resistance, inductance, capacitance and impedance | * Learners to understand that different components have different effects on alternating current (AC) circuits, and these effects vary with frequency depending on the components in the circuit. * Learners to understand that resistance in an AC circuit has no effect on the waveform except to limit the current. |
| * 1. Calculation of electrical quantities in alternating current circuits | * Learners to perform calculations using quantities in AC circuits including: * resistance * inductance * inductive reactance * capacitive reactance * capacitance * impedance. * Learners to be familiar with worked examples of all the calculations including formulae and waveform diagrams required at this level in Tanner, *Book 2*, Ch 2. |
| * 1. Operating principles of electro-mechanical components | * Learners to understand the operating principles of electro-mechanical components including: * contactors * relays * solenoids. * Learners to be shown a practical demonstration of the effects of electromagnetism using contactors (direct on-line (DOL) starter) and simple relays and solenoids. |
| * 1. Types of transformers | * Learners to understand the different types of transformers, including: * step-up and step-down transformers as used in power grid networks * transformers with a 1:1 ratio used for electrical separation * encapsulated transformers used in separated extra-low voltage (SELV) such as downlights and bathroom fans * toroidal transformers used in switch mode power supplies. |
| * 1. The operating principles, applications and limitations of transformers | * Learners to understand the principles, applications and limitations of a transformer, including: * losses that occur in a transformer, such as iron loss and copper loss * the relationship between current and voltage * the ratio of primary to secondary turns (windings) * the ratio of primary to secondary voltage * the ratio of primary to secondary currents. * Learners to understand that transformers will be either step up or step down, dependant on their use (unless 1:1 ratio is required). * Learners to understand that the rating of a transformer is a classification in terms of apparent power VA (or kVA) as opposed to watts for resistive components. |
| * 1. The relationship between kW, kVAr, kVA and power factor | * Learners to understand that for an AC system: * true power is measured in watts or kW * reactive power is measured in Var or kVar * apparent power is measured in VA or kVA * power factor is a ratio of true power to apparent power (no units). * Learners to be familiar with the systematic approach to these relationships in Tanner, *Book 2*, Ch 2. |
| * 1. Power factor improvement | * Learners to understand power efficiency is at a maximum when the power factor is unity. * Learners to understand that lagging power factors exist in inductive circuits. * Learners to understand that a capacitor is used across the supply terminals of an inductive load to oppose the lagging power factor created by the inductor (power factor correction). * Learners to understand that, in an industrial system, an automatic capacitor bank can be used to control the power factor correction. |
| * 1. Voltage and current in star and delta connected systems | * Learners to understand that: * star and delta systems of power are used throughout the building services industry and each has different characteristics in terms of voltage and current * in a star connected system, the line current and phase currents are equal * in a star connected system, the line voltage is 1.73 times larger than the phase voltage (note that 1.73 is √3) * in a delta connected system, line and phase voltages are equal * in a delta connected system, the line current is 1.73 times larger than the phase current (note 1.73 is √3). |
| * 1. Advantages of balanced star connected systems | * Learners to understand that: * in a balanced star connected system (all loads have equal impedances) there is no need to have a star point connection * in practice, a balanced star system is difficult to achieve. |
| * 1. The neutral current in a three-phase star connected system | * Learners to understand that: * when a star system is unbalanced, a current will exist in the neutral * the neutral current can be calculated by phasor diagram analysis, application of formula and equilateral triangle analysis. |
| 1. Understand the operating principles and applications of DC machines and AC motors | * 1. The basic types, applications and operating principles of DC machines | * Learners to be able to describe the operating principles of DC machines. * Learners to understand the different types of DC machines: * series wound * shunt wound * compound wound. * Learners to understand that: * series wound DC machines can be used where high starting torque is required * a shunt DC machine can be used where a constant speed is required * a compound wound machine has both series and shunt connected windings. |
| * 1. The operating principles of AC motors | * Learners to understand: * the operating principles of AC motors as producing a torque through the interaction between magnetic fields * that the magnetic fields in an AC motor are developed within the stator and rotor. |
| * 1. State the basic types, applications and limitations of AC motors | * Learners to understand: * that AC motors can be single phase or three phase * that single-phase AC motors can be induction, capacitor start, split phase or synchronous types * that three-phase motors can be induction and wound rotor types * the application of each type of motor and its limitations. * Learners to be shown stripped-down examples of these components to identify the different stators and rotors for each type. An animated video on how an induction motor works is available from YouTube (see Suggested resources). |
| * 1. The basic operating principles, limitations and applications of motor control | * Learners to understand different motor control systems, such as: * direct on-line starter * star-delta starter * rotor-resistance * soft start * variable frequency. * Learners to understand the operating principles of motor control systems. * Learners to understand motor control applications such as controlling the speed of conveyers, cranes, hoists, machine tools, pumps and blowers and their limitations. |
| 1. Understand the principles and applications of electrical lighting systems | * 1. The basic principles and applications of illumination | * Learners to understand: * the basic principle of the inverse square law for lighting and the cosine law * the applications of general lighting service (GLS), discharge lighting and energy-saving lighting including limitations. |
| * 1. The operating principles, types, limitations and applications of luminaires | * Learners to understand: * the operating principles of GLS, discharge and energy-efficient luminaires * types of GLS such as tungsten and halogen * types of discharge lighting such as low- and high-pressure mercury vapour, low- and high-pressure sodium vapour and metal halide * energy-saving lighting such as compact fluorescent lamps and LEDs * the applications of different lighting types, such as digital addressable lighting interface (DALI), and their limitations. |
| 1. Understand the principles and applications of electrical heating systems | * 1. The basic principles of electrical space heating and electrical water heating | * Learners to understand the basic operating principles of electrical space heating, including: * convection * conduction * radiation. * Learners to understand the basic operating principles of electrical water heating, such as the heating effect of an electric current by passing a current through a wire. |
| * 1. The operating principles, types, limitations and applications of electrical space and water heating appliances and components | * Learners to understand the different types of electrical space and water heating, including: * immersion heaters * storage heaters * convector heaters * underfloor electric heating. * Learners to understand that heating systems require controls such as timers and programmers. * Learners to understand the limitations of each type of heating system. |
| 1. Know the types, applications and limitations of electronic components in electrical systems and equipment | * 1. The basic operating principles of electronic components and devices | * Learners to understand the basic operating principles of electronic components and devices, including: * capacitors * resistors * rectifiers * zener diodes * LEDs * photo diodes * thermistors * diacs * triacs * transistors * thyristors * invertors. |
| * 1. The function and application of electronic components that are used in electrical systems | * Learners to understand that electronic components used in electrical systems are applied to: * security alarms * telephones * dimmer switches * heating/boiler controls * motor controls * wireless control systems * solar PV systems. * Learners to be able to identify the electronic components and devices listed, both from circuit symbols and physical appearance. |