Unit 74: Aircraft Electrical Devices and Circuits

Unit code: D/600/7213

QCF Level 3: BTEC Nationals

Credit value: 10

Guided learning hours: 60

Aim and purpose

This unit will develop learners' understanding of the application of electrical components and systems to the generation, distribution and utilisation of electricity in aircraft and aerospace applications.

Unit introduction

Modern aircraft rely on an increasingly sophisticated range of electrical components and systems used in the generation, distribution and utilisation of electrical energy. These components include resistors, capacitors, inductors, transformers, generators and alternators and the systems in which they are used include those for electrical generation, power control and regulation, and electromechanical actuators and rotating machinery.

This unit will develop learners understanding of electrical terminology and the methods use to produce electricity, in particular the construction and characteristics of aircraft batteries as a means of producing direct current (DC) electricity. Learners are then taken through the theory, construction and operation of resistive, capacitive and inductive devices and their use in electrical circuits and components such as transformers. Finally, learners will apply AC theory and their knowledge of magnetism and inductance to the construction, operation and distribution of electrical energy in both single and three-phase systems.

The unit also provides some of the knowledge and understanding for learners wishing to progress on to the European Aviation Safety Agency (EASA) Part 66 licensing requirements.

Learning outcomes

On completion of this unit a learner should:

1 Understand the theory and terminology related to static and direct current (DC) electricity and the methods and devices used to produce it

2 Understand the theory, construction and operation of resistive and capacitive devices

3 Be able to apply relevant alternating current (AC) theory to determine circuit parameters

4 Be able to apply the theory of magnetism to the construction and operation of electromagnetic components and AC generators.

Unit content

1 Understand the theory and terminology related to static and direct current (DC) electricity and the methods and devices used to produce it

Theory and terminology: atomic structure and electrical charge; conduction in solids, liquids and gasses; conductance; conventional current flow; electron flow; distribution of electrostatic charge; electrostatic laws of attraction and repulsion; Coulomb's law

Methods and devices used to produce electricity: generation of electricity by light, heat, friction and pressure; construction and basic chemical action of primary and secondary cells eg lead acid, nickel cadmium and alkaline types; series and parallel connection of cells eg terminal voltage, internal resistance and its effect on terminal voltage and load current supplied by a battery

2 Understand the theory, construction and operation of resistive and capacitive devices

Theory and terminology: factors affecting resistance eg conductor length, cross sectional area, specific resistance (resistivity), temperature and coefficient of resistance; factors affecting capacitance eg plate spacing plate area dielectric constant (permittivity)

DC circuit theory: relationship between voltage, current, resistance and power; relationship between charge, voltage, capacitance and energy stored in a capacitor; charge and discharge of the capacitor (exponential growth and decay of voltage and current, and time constant)

Resistive devices: construction, properties and characteristics of different types of resistor eg carbon film, metal film and wire-wound types, variable resistors (rheostats), potentiometers, voltage dependent resistors (VDRs); thermistors (positive temperature coefficient (PTC) and negative temperature coefficient (NTC)); light dependent resistors (LDRs); ratings, markings and colour code eg preferred values, tolerance, power rating; methods used for testing and measuring resistance eg ohmmeter and Wheatstone bridge

Capacitive devices: construction of different capacitor types eg air-spaced, multi-plate types, axial and radial types; variable capacitors; markings and colour code; ratings (preferred values, voltage rating); methods used for testing capacitors eg open and short circuit tests

3 Be able to apply relevant alternating current (AC) theory to determine circuit parameters

AC theory: relationship between resistance, reactance and impedance (the impedance triangle, phase angle and power factor); variation of reactance with frequency (both inductive and capacitive reactance); phasor diagrams; true power and apparent power; determination of the voltage, current and power in series, parallel, and series-parallel circuits containing a combination of resistance and reactance (both inductive and capacitive); resonance, Q-factor and bandwidth; power factor correction

Transformers: transformer principles eg primary and secondary voltage, current and power relationships, turns ratio, turns per volt; transformer types eg step-up, step-down, isolating, autotransformers, three-phase transformers; transformer losses (iron, copper); transformer conditions eg under no-load, on-load; power loss and efficiency; calculation of line and phase voltages and currents; calculation of power in three-phase systems

4 Be able to apply the theory of magnetism to the construction and operation of electromagnetic components and AC generators

Magnetism: action of a magnet suspended in the earth's magnetic field; magnetic shielding; types of magnetic material; construction and types of material used

Electromagnetic theory: Faraday's law; induced electromotive force (emf); principles of electromagnetic induction; relationship between induced emf, magnetic field strength, number of conductor turns and rate of change of flux; self and mutual inductance; relationship between number of turns, magnetic length, permeability, and inductance; generator theory (rotation of a loop in a magnetic field and the waveform generated); power delivered to a load in single-phase and three-phase (balanced condition only) AC circuits

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 explain electrical theory and terminology	**M1** carry out functional tests on three types of resistor and three types of capacitor used in aircraft and aerospace applications	**D1** measure the voltage and current in a C-R circuit during charge and discharge and verify the results obtained by calculation
P2 describe the different methods used for producing electricity	**M2** measure the voltage, current, power and power factor in a single-phase AC circuit containing a series combination of resistance and reactance, and verify the results obtained by calculation.	**D2** measure the line and phase voltage, current and total power present in a three-phase AC circuit and verify the results obtained by calculation.
P3 explain factors affecting resistance and use DC circuit theory to determine the resistance, current, voltage and power in a simple circuit with a battery and a resistor and solve series/parallel circuits with up to four resistors		
P4 describe the construction, characteristics, properties, ratings, markings and colour codes used for two types of resistive device and the methods used for testing and measuring resistance		
P5 explain factors affecting capacitance and use DC circuit theory to determine the charge, voltage, current, capacitance and energy stored in a simple circuit with a battery, resistor and a capacitor and solve series/parallel circuits with up to four capacitors		

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:**
P6	describe the construction, ratings, markings and colour codes used for two different types of capacitor and the methods used for testing and measuring capacitance		
P7	use AC theory to determine circuit parameters (voltage, current, impedance, phase angle, Q-factor, resonant frequency, bandwidth, power, and power factor) in an AC circuit containing a combination of resistance and reactance and apply power factor correction techniques [IE1, IE4]		
P8	explain the transformer principle, losses in transformers and determine circuit parameters (primary and secondary voltage, current, power, power loss and efficiency) when a transformer is connected to a purely resistive load [IE1, IE4]		
P9	describe the key types and constructional features of magnetic materials		
P10	use appropriate theory to determine single and three-phase circuit solutions relating to electromagnetic components and alternating current generators.		

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

Essential guidance for tutors

Delivery

All four learning outcomes are linked and the delivery strategy should ensure that these links are maintained. Learning outcome 1 is the most likely starting point for delivery, as it will establish much of the underpinning knowledge and skills required for the remaining learning outcomes.

The unit could be delivered through a combination of theory lessons and demonstrations, reinforced through practical work in an electrical workshop or laboratory. It is important that learners have a thorough understanding of circuit theory if they are to be able to understand the operation of complex electrical and electronic systems found in modern aircraft and aerospace applications.

Learners should be given plenty of opportunity to put into practice the theory covered in the unit content. They should be able to select the most appropriate formulae to determine the required circuit values of current, voltage, power and power factor. Learners should also be able to transpose equations to meet their needs (eg rearrange $Z = \sqrt{R^2 + X^2}$ and then use given values of Z and R to find X). It is important that *Unit 4: Mathematics for Technicians* has been delivered or is being delivered concurrently with this unit to give learners the necessary mathematical skills.

Delivery of learning outcome 2 could be based on a series of investigations in to typical components found in aircraft and aerospace applications. Learners should be introduced to each type of component as well as its construction and operation. They should learn to recognise components from their markings, colour codes, and physical appearance and should be introduced to the methods used for carrying out simple tests and measurements using a multimeter in order to confirm their value and operational status.

Learning outcome 3 will extend learners' understanding of AC principles to circuits containing a mixture of resistance and reactance. Learners should be introduced to theoretical concepts (such as the impedance triangle, phasor diagrams and power factor calculation) before investigating practical applications in which these circuits are used (such as power factor correction, resonant circuits and filters). Learners also need to be introduced to transformers including non-ideal components in which iron and copper losses are present.

Learning outcome 4 can be delivered through an investigation of a variety of components used in aircraft AC electrical systems. Learners should practice solving single-phase and three-phase circuits (balanced condition only) and should be shown how to determine the power present in a three-phase load when given the line voltage, line current and power factor.

Wherever possible, learners should be given opportunities to experience a range of electrical test equipment (specifically multimeters) that reflect typical and current use in the aerospace industry. Tutors should also ensure that learners are aware of the safe use of multimeters (and the need for routine inspection and calibration) in an aircraft workshop and industry setting.

Centres should relate theory to real aircraft and practical aerospace applications wherever possible. Industrial visits or work experience could be used to support learning and provide learners with an appreciation of the use of electrical components and systems within the aerospace industry. Learners should be encouraged to make reference to relevant aircraft maintenance manuals for recommended procedures and information on the operation of components and systems.

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: • explain the theory and terminology related to electrical charge, conduction and current flow • explain electrostatic theory, Coulomb's Law and related terminology • explain the generation of electricity and the construction, function and series and parallel connection of primary and secondary cells.
Prepare for and carry out **Assignment 1: Sources of Electricity** (P1, P2).
Whole-class teaching: • explain the factors affecting resistance and capacitance • explain the relationship between voltage, current, resistance and power • explain the relationship between charge, voltage, capacitance and energy stored in a capacitor • explain the main construction, properties and characteristics of a range of resistive devices • explain the main construction, properties and characteristics of a range of capacitive devices. *Practical workshop activities:* • investigation of a range of aircraft resistive and capacitive components.
Prepare for and carry out **Assignment 2: Electrical Components** (P3, P4, P5, P6, M1, D1).
Whole-class teaching: • explain the impedance triangle, phasor diagrams and power factor • explain variation of reactance with frequency • explain and demonstrate how to determine circuit parameters. *Practical workshop activities:* • investigation of a range of aircraft series, parallel, and series-parallel circuits *Whole-class teaching:* • describe the main types of transformer and explain the underlying principles of operation • explain and demonstrate calculation of line and phase voltage and current • explain and demonstrate calculation of power in three-phase systems. *Practical workshop activities:* • investigation of a range of transformers.
Prepare for and carry out **Assignment 3: AC Circuits** (P7, P8, M2, D2).
Whole-class teaching: • explain magnetism and the main principles of electromagnetic theory • explain and demonstrate solving single-phase and three-phase circuits. *Practical workshop activities:* • investigation of a range of aircraft AC electrical system components.
Prepare for and carry out **Assignment 4: Electromagnetic Components** (P9, P10).
Review of assessment and feedback to learners.

Assessment

Assessment evidence for this unit could be developed through a combination of written reports, practical investigations and conventional written examinations with short and long answer questions.

The method of assessment preferred by national legislative bodies relative to the aerospace industry involves the use of multiple choice questions. Many centres may have existing banks of multiple choice questions designed to prepare and test learners for Module 3 of EASA Part 66. Where learners are aiming to achieve recognised licensed status, this method of assessment could be adopted as a means of supporting and checking learning. However, multiple-choice questions should not be used as assessment instruments for the purposes of this unit.

It is likely that at least four assessment instruments will be required for this unit. If practical investigations and tests are also used then the total number of pieces of assessed work could be even greater. This should be carefully considered so that it does not place an unduly heavy assessment burden on learners or the tutor.

Clearly, the ability to work safely in an aircraft environment should be paramount and centres should ensure that learners understand relevant hazards, such as high voltages in aircraft three-phase AC systems and leakage of electrolyte in the vicinity of aircraft batteries.

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	Sources of Electricity	Learners investigate the theory and terminology related to static and DC electricity.	A formal written assignment requiring learners to respond to written tasks.
P3, P4, P5, P6, M1, D1	Electrical Components	Learners investigate a range of different electrical components.	A formal written assignment requiring learners to respond to written tasks.
P7, P8, M2, D2	AC Circuits	Learners need to determine the parameters of AC circuits.	A written report based on practical tasks.
P9, P10	Electromagnetic Components	Learners investigate a range of different electromagnetic components.	A written report based on practical tasks.

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
		Mathematics for Technicians
		Further Electrical Principles

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

- Unit 178: Overhauling Components of Aircraft Electrical Equipment
- Unit 121: Undertaking Scheduled Maintenance of Aircraft Avionics Equipment/Systems
- Unit 134: Carrying Out Tests on Aircraft Electrical Power Control, Distribution and Protection Systems

Essential resources

It is essential that learners have access to a well equipped electrical workshop or electrical laboratory, with up to date electrical test instruments such as digital and analogue multimeters, generators and oscilloscopes. Centres should also provide a range of typical electrical components used in aircraft and aerospace applications. Learners would benefit from access to 'live' aircraft, spare parts and maintenance information found in a typical aviation technical library.

Employer engagement and vocational contexts

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 Circuit Theory and Technology* (Newnes, 2007) ISBN 075068139X

Bird J O – *Electrical and Electronic Principles and Technology* (Newnes, 2007) ISBN 0750685565

Dingle L and Tooley M – *Aircraft Engineering Principles* (Elsevier, 2005) ISBN 075065015X

Eismin T – *Aircraft Electricity and Electronics* (McGraw-Hill, 1994) ISBN 0028018591

Robertson C R – *Fundamental Electrical and Electronic Principles* (Butterworth-Heinemann, 2001) ISBN 0750651458

Delivery of personal, learning and thinking skills

The table below identifies the opportunities for personal, learning and thinking skills (PLTS) that have been included within the pass assessment criteria of this unit.

Skill	When learners are ...
Independent enquirers	identifying questions to answer and problems to resolve and analysing information when determining circuit parameters.

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 ...
Reflective learners	setting goals with success criteria for their development and work
Team workers	collaborating with other when working as part of a team to investigate aircraft electrical devices.

Functional Skills – Level 2

Skill	When learners are ...
English	
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	explaining the construction, and properties of aerospace electrical components and systems
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	explaining the construction, and properties of aerospace electrical components and systems.