Unit 30: Applied Electrical and Mechanical Science for Engineering

Unit code: A/600/0387

QCF Level 2: BTEC First

Credit value: 5

Guided learning hours: 30

Aim and purpose

This unit gives learners the opportunity to explore the scientific concepts and principles associated with electrical and mechanical engineering.

Unit introduction

This unit will give learners an opportunity to investigate many electrical and mechanical engineering units such as charge, current, voltage, resistance and power; mass, weight, force, density, velocity and acceleration. The definitions of these units will be explained and their mathematical interrelationships investigated. These mathematical relationships can be investigated experimentally and the learners will be able to experience how slight experimental error and other factors can cause differences between actual and expected values. A capable engineer is one who knows what level of error is acceptable in different given circumstances.

The unit will cover the parameters of direct electrical current and magnetic fields within the context of electrical and magnetic circuits. Learners will also examine the definitions and parameters of static and dynamic systems including statics, linear motion and the properties and behaviour of fluids.

Although the content lends itself to a theory-based delivery approach there is scope for experimentation and a practical approach to certain elements of the learning outcomes.

This unit provides the underpinning knowledge that will be used across other units within the qualification and for progression to further levels.

Learning outcomes

On completion of this unit a learner should:

1 Be able to define and apply concepts and principles relating to electrical science

2 Be able to define and apply concepts and principles relating to mechanical science.

Unit content

1 Be able to define and apply concepts and principles relating to electrical science

Definitions of parameters of direct current: electrical charge; electric current; electro-motive force; electrical resistance; electrical power

Definitions of parameters of magnetic fields: magnetic fields; magnetic flux and flux density

Direct current electrical circuits: circuit symbols; Ohm's Law; potential difference; current; resistance in series and parallel circuit networks; data for calculations

Magnetic circuits: force on a current-carrying conductor; construction, function and use of electro-magnetic coils eg relays, contactors, solenoids, sensors, motors, transformers; data for calculations

2 Be able to define and apply concepts and principles relating to mechanical science

Definitions of parameters of static and dynamic systems: mass; weight; force; moment of a force; density; relative density; displacement; velocity; acceleration; work; power

Statics: conditions for static equilibrium, parallelogram, triangle and polygon of forces; principle of moments; limiting coefficient of kinetic friction; frictional resistance to motion; data to determine resultants; equilibrants and reactions

Linear motion: displacement; velocity; acceleration; formulae for uniform acceleration and retardation; graphical representation of displacement against time and velocity against time; work done; power dissipated; data to determine acceleration/retardation

Properties and behaviour of fluids: absolute and gauge pressure; pressure at depth in a fluid; data to determine pressure

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 define parameters of direct current electricity and magnetic fields	**M1** determine the force on a current carrying conductor situated in a magnetic field from given data	**D1** explain the construction, function and use of an electro-magnetic coil
P2 determine total resistance, potential difference and current in series and parallel dc circuits from given data [IE3, IE4]	**M2** describe the conditions required for the static equilibrium of a body.	**D2** determine the work done and the power dissipated in moving a body of given mass along a horizontal surface at a uniform velocity, given the value of the coefficient of kinetic friction between the contact surfaces.
P3 define parameters of static and dynamic mechanical systems		
P4 determine the resultant and equilibrant of a system of concurrent coplanar forces from given data [IE3, IE4]		
P5 determine the uniform acceleration/retardation of a body from given data [IE3, IE4]		
P6 determine the pressure at depth in a fluid from given data. [IE3, IE4]		

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

Where a single group contains learners from a number of engineering disciplines, such as plant and operations, mechanical, etc, it is important that delivery of the content is placed within an appropriate context to meet the individual needs of each learner.

There is no set order for the delivery of the two learning outcomes and tutors will each have their own preferences with regards to the best point to start. The order of delivery of the learning outcomes may well be determined by the make up of the group. That is, a group of electronics or maintenance learners may benefit from considering the first learning outcome – concepts and principles of electrical science, since they may see this as having immediate relevance. This could then be followed with the work on mechanical science, delivered as far as possible with a focus on its relevance to electronics or maintenance. Of course, this could be reversed for general engineering learners.

The unit lends itself to a range of tutor demonstrations and practical work and centres should strive to include as much hands on work for the learners as possible to bring the science alive. In most cases, expensive equipment is not required – for example building simple circuits on re-usable bread-boards, setting up a force board with pulleys to determine triangles and polygons of forces, arranging inclined planes for the determination of coefficient of friction between a range of materials.

When carrying out practical work with direct current circuits it is acceptable to use either real components and circuits or CAD simulation. It is recommended however, that the learner does have some contact and experience with real electronic components during the delivery of the unit.

Ultimately, the learning come down to the ability of the learner to gain a sufficient understanding of the concepts to enable them to solve, through calculation in most cases, relevant engineering problems. To this end, a large amount of the time available for delivery will be spent going through worked examples with the learners and then allowing the learner to tackle similar and varied problems.

The unit provides the underpinning knowledge for many other units in the qualification and should be delivered at an early stage in the programme of study. There is a strong correlation between this unit and *Unit 3: Mathematics for Engineering Technicians* and both units could be delivered in parallel.

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 relevance of science to engineering, unit content, the scheme of work and assessment strategy • consider the definitions of common quantities and SI units. Group work: • explore and compare calculator types, review common functions and carry out calculator use exercises. Individual learner activity: • complete worksheet on common quantities and SI units.
Whole-class teaching: • explain the terminology used to describe the parameters of direct current and their associated symbols and units • tutor demonstration of an electrical circuit using components or computer simulation • develop practical circuits to show series and parallel connection of resistors • explain the formulae used for Ohms law and resistors in series and parallel followed by individual learner activity involving calculations using formulae • explain the terminology used to describe the parameters of magnetic fields and their associated symbols and units, current-carrying conductors and solenoids • tutor demonstration of magnetic fields and solenoids • define flux, flux density and state formula for calculation of force on a current carrying conductor in a magnetic field • tutor demonstration of the use of formula for the calculation of force on a current carrying conductor in a magnetic field and explain determination of direction of force. Individual learner activity: • exercises on solution of circuit problems involving force on a conductor. Whole-class teaching: • describe and discuss the principle of operation and practical applications of relays, contactors and solenoids, basic dc motors and transformers • tutor demonstration of the calculation of output emf for no load condition. Individual learner activity: • tutor-led revision exercises on dc circuits and force on a conductor.
Prepare for and carry out assignment 1 (P1, P2, M1, D1).

Topic and suggested assignments/activities and/assessment
Whole-class teaching: • consider mass, weight, concurrent and non-concurrent coplanar forces and the moment of a force and conditions required for static equilibrium • tutor demonstrate of the construction of parallelogram, triangle and polygon of forces. Individual learner activity: • exercises on graphical solution of concurrent coplanar force systems. Whole-class teaching: • explain the principle of moments and its applications with examples of calculations to determine simply supported beam reactions and solution of other simple non-concurrent coplanar force systems. Individual learner activity: • exercises on solution of non-concurrent coplanar force systems. Whole-class teaching: • explain and discuss Coulomb's laws for dry frictional resistance between surfaces in sliding contact, coefficient of kinetic friction and demonstrate calculation of frictional resistance to motion • practical activity to determine coefficient of friction • consider – density and relative density, common – units of pressure, absolute and gauge pressure, pressure at depth below the free surface of a liquid. Individual learner activity: • exercises on pressure calculation and measurement.
Prepare for and carry out assignment 2 (P6).
Whole-class teaching: • consider – displacement, velocity and acceleration, displacement-time and velocity-time graphs, formulae for motion with uniform acceleration • tutor demonstration of calculations to solve problems relating to linear motion from given data. Individual learner activity: • exercises on motion with uniform acceleration. Whole-class teaching: • consider Newton's law's of motion and inertia, develop formula for calculation of inertial resistance from Newton's 2nd law of motion, work and power • tutor demonstration of calculations using Newton's laws of motion and inertia. Individual learner activity: • exercises on motion with uniform acceleration involving work and power.
Prepare for and carry out assignment 3 (P3, P4, P5, M2, D2).
Feedback on assessment, unit evaluation and close.

Assessment

Evidence of achievement of the learning outcomes and Assessment and grading criteria may be obtained from well planned and supervised investigative assignments and/or through the responses to given engineering problems and questions that cover the requirements of the assessment criteria and related content.

It is expected that learners should demonstrate an acceptable range of accurate responses made in standard or engineers' form (eg 1.2×10^4 or 12×10^3). Solutions to problems should include a reasonable display of number skills demonstrated by the appropriate application and manipulation of formulae, suitable accuracy of calculations and, where applicable, statement of correct units.

Three assignments could be used for the assessment of this unit. The first might cover P1, P2, M1 and D1 and include questions that require learners to define parameters of direct current electricity and magnetic fields (P1) and solve direct current electrical circuit problems (P2). A task could also be set within this assignment to provide the learner with an opportunity to achieve M1 by the determination of the force on a current carrying conductor situated in a magnetic field. Finally, given a diagram of an electro-magnetic coil, the learner could achieve D1 by explaining its construction, function and use.

The second assignment could cover the criteria P3, P4, P5, M2, D2 – static and dynamic systems. The first task of the assignment could cover the basic definitions (P3) but these could also be integrated into the tasks associated with P4, P5 (and P6 related to assignment 3). For example, before the learner calculates the moments of a force they might be asked to define or state what is meant by a moment of a force. This approach has the potential of making the learner's definitions of the parameters more relevant and less disjointed. The design of the tasks for P4 and P5 should be such that they sufficiently cover the criteria and related content. Additional tasks or extensions to the tasks for P4 and P5 could then be suitably integrated into the assignment to enable the learner to the work towards the achievement of M2 and D2.

The third assignment, based around given data on a static fluid system, could be used enable the learner to demonstrate the determination of hydrostatic pressure at a depth in a fluid to achieve P6 and also the definitions of parameters required under P3 that are relevant to fluid systems – density and relative density.

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, M1, D1	Electricity and Magnetism	An activity requiring learners to complete four tasks that together define given parameters, determine calculations from given data and describe functions relating to current electricity and magnetic fields.	A report containing written responses on electricity and magnetism.
P3, P4, P5, M2, D2	Statics, Dynamics and Linear Motion	A written activity based on the parameters and solution of engineering problems relating to statics and linear motion.	A report containing written responses about static and dynamic system problems, determination of a system of coplanar forces plus calculations relating to uniform acceleration/retardation of a body.
P6	Fluid Pressure	A written activity requiring learners to carry out calculations relating to engineering problems associated with pressure in fluids.	A report containing the results of calculations to determine the properties and behaviour of a fluid.

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. The unit has particular links with the following unit titles in the Engineering suite:

Level 1	Level 2	Level 3
	Mathematics for Engineering Technicians	Mechanical Principles and Application
		Electrical and Electronic Principles

Essential resources

Learners will need access to engineering science laboratory facilities to enable practical experimentation and tutor demonstrations.

Employer engagement and vocational contexts

Delivery and assessment of this unit can be reinforced with company visits. Such visits can help learners understand how many of the concepts in electrical and mechanical engineering relate to industry. They would also enable learners to put the concepts into perspective, for example a visit to an electrical power station would enable learners to appreciate the potential scale of electro-magnetic equipment, engineering structures and the forces that these can be required carry.

There is a range of organisations that may be able to help centres engage and involve local employers in the delivery of this unit, for example:

- 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 – *Science for Engineering* (Newnes, 2003) ISBN 0750657774

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

Bolton W – *Engineering Science* (Newnes, 2006) ISBN 0750680830

Hannah J and Hillier M J – *Applied Mechanics* (Longman, 1995) ISBN 0582256321

Tooley M – *BTEC First Engineering* (Newnes, 2006) ISBN 9780750680608

Website

www.howstuffworks.com

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	exploring issues and problems relating to electrical and mechanical engineering science analysing data and evaluating its relevance and value.

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	reviewing progress when solving problems during the learner's activities and acting on the outcomes to make corrections to understanding/solutions
Self-managers	organising time and resources to carry out practical work relating to electrical and mechanical engineering science experiments and investigations
Creative thinkers	trying out alternatives or new solutions to electrical and mechanical engineering science problems
Team work	collaborating with others when working on practical and investigative group work to achieve a valid solution.

Functional Skills – Level 2

Skill	When learners are ...
Mathematics	
Understand routine and non-routine problems in a wide range of familiar and unfamiliar contexts and situations	solving routine electrical and mechanical problems set within 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 and mechanical situations
Select and apply a range of skills to find solutions	selecting and applying formulae to solve electrical and mechanical science problems in engineering settings
Use appropriate checking procedures and evaluate their effectiveness at each stage	checking the results of solutions to electrical and mechanical 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 supervisors to establish an understanding of electrical and mechanical engineering science concepts and issues
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	selecting, reading and using appropriate electrical and mechanical science 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 and mechanical science problems to communicate accurate solutions effectively.