Unit 67: Principles and Applications of Aircraft Mechanical Science

Unit code: M/600/7183

QCF Level 3: BTEC Nationals

Credit value: 10

Guided learning hours: 60

Aim and purpose

This unit has been designed to develop the skills needed to apply aircraft mechanical, fluid and thermodynamic principles.

Unit introduction

The study of mechanical science is essential for anyone who wishes to understand the underlying principles and ways in which aircraft engineering systems function. This unit has been designed to develop knowledge and understanding of aircraft mechanical, fluid and thermodynamic systems. It will be useful for those engaged in the manufacture or maintenance of aircraft structures and mechanical systems.

Learners will apply their knowledge of mechanical science to the static loads imposed on aircraft jointed structures and will determine desired parameters of an aircraft when treated as a loaded beam. Learners will apply kinetic and dynamic principles to the solution of problems involving aircraft motion and manoeuvres as well as to aircraft lifting systems.

Fluid principles concerned with external and internal fluid flows are covered and applied to flow and pressure over aerofoil surfaces, and flow through ducts and piped systems.

Learners will study thermodynamic principles in order to understand such applications as; the expansion of aircraft materials, aircraft cooling systems, practical reciprocating piston engine cycles and aircraft gas turbine engine cycles.

This unit will be of benefit not only to learners studying at BTEC National level but also those following an apprenticeship in aircraft manufacture or maintenance, as well as those undergoing aircraft engineering training with the armed forces. The unit also provides some of the underpinning knowledge required for the European Aviation Safety Agency (EASA) Part 66 examinations.

Learning outcomes

On completion of this unit a learner should:

1 Be able to apply mechanical principles to determine forces and stresses in static aircraft engineering systems

2 Be able to apply mechanical principles to determine parameters of aircraft kinetic and dynamic systems

3 Be able to apply fluid principles to determine parameters of aircraft fluid flows

4 Be able to apply thermodynamic principles to determine the parameters of aircraft thermodynamic systems.

Unit content

1 Be able to apply mechanical principles to determine forces and stresses in static aircraft engineering systems

Forces and stress: force $(F = ma = mg)$, mass/weight relationship $(W = mg)$ static pressure $(P = L/A)$ vector representation of forces and couples; simply supported beams (weight of beam, concentrated load, uniformly distributed load, reactions); stress (direct, shear)

Mechanical principles: principle of moments and conditions for static equilibrium; expressions/formulae eg for direct stress, strain, shear stress and strain, elastic modulus (tensile, shear), torsion, stress in components subject to single and double shear, factor of safety

Static aircraft engineering systems: eg stresses in aircraft structures (such as tensile, shear, torsion, bending and hoop stresses in fuselage, wings, undercarriage), aircraft fuselage as a simply supported beam (centre of gravity (CG), datum, CG limits), aircraft fastened joints (such as riveted, bolted, hinge pins)

2 Be able to apply mechanical principles to determine parameters of aircraft kinetic and dynamic systems

Parameters: kinetic eg uniform motion, linear motion under constant acceleration, motion under gravity, centripetal acceleration, periodic motion, pendulum motion, harmonic motion, uniform circular motion, velocity ratio, mechanical advantage, effort and load motion; dynamic eg centripetal force, inertia, thrust force, impulse $= vt$, applied torque, power $= T\omega$, vibration, resonance, load and effort force, frictional force $F = \mu R$, static and dynamic friction

Mechanical principles: Newton's laws of motion; equations of motion and forces due to motion (such as, $s = \frac{(u+v)t}{2}$, $v = u + at$, $v^2 = u^2 + 2as$, $s = ut + \frac{1}{2}at^2$, $a = \omega^2 r$ or $a = v^2/r$, $F = ma$ inertia force $F_c = m\omega^2 r$, and $Fc = mv^2/r$); lifting system principles (such as velocity ratio, mechanical advantage, friction effects, efficiency); friction (such as coefficient of friction static and dynamic friction); work, energy (potential, kinetic), power

Application of principles: eg aircraft motion along runway, aircraft braking, engine thrust forces and power, rotating machines, aircraft flight manoeuvres (such as steady turn, angle of bank $\tan\theta = \frac{v^2}{gr}$, pull out from a dive, loop, take-off, landing and taxing), aircraft lifting systems (such as aircraft lifting screw jack, trestles, engine hoists, pulley systems)

3 Be able to apply fluid principles to determine the parameters of aircraft fluid flows

Parameters: fluid motion eg static, dynamic and total pressure, velocity, density, relative density, viscosity, incompressible flow, compressibility effects, laminar and turbulent flow, Reynold's number, boundary layer, transition point

Fluid principles: governing laws and equations eg equations of continuity

($\dot{Q} = A_1 v_1 = A_2 v_2$, $\dot{m} = \rho_1 A_1 v_1 = \rho_2 A_2 v_2$), Bernoulli's theorem for incompressible flow

($p_1 + \frac{1}{2}\rho v_1^{\,2} = p_2 + \frac{1}{2}\rho v_2^{\,2} = C$),

Reynold's equations eg $Re = \dfrac{\rho V l}{\mu}$ external flow, $Re = \dfrac{\rho V d}{\mu}$ internal flow

Aircraft fluid flows: eg airflow pressures, density and velocities through convergent/divergent ducts, internal and external flows (such as laminar and turbulent flows through piped systems and over aerofoil surfaces)

4 Be able to apply thermodynamic principles to determine parameters of aircraft thermodynamic systems

Parameters: fundamental parameters (thermodynamic temperature, specific heat capacity at constant volume and constant pressure, ratio of specific heat, linear thermal expansion $x = \alpha \Delta t l$, latent heat, thermal energy $Q = mc\Delta t$, thermal power $\dot{Q} = \dot{m}c\Delta t$); heat transfer by conduction, convection and radiation; temperature scales (Celsius, Kelvin and Farenheit) and temperature conversion; thermodynamic process parameters eg reversible/irreversible, constant volume, constant pressure, ideal, practical)

Thermodynamic principles: ideal gas laws (Boyles, Charles, and combined gas law), characteristic gas equation; governing laws and processes eg first law of thermodynamics, second law of thermodynamics, open and closed systems, the heat pump, thermodynamic processes (such as, polytropic, isentropic, adiabatic), P-V diagrams, ideal constant volume cycle, T-S diagrams, ideal constant pressure cycle

Aircraft thermodynamic systems: eg temperature measurement systems (thermometers, pyrometers), oleo struts, accumulators, piston engine practical four-stroke cycle,, gas turbine engine practical cycle, cooling systems (such as vapour cycle cooling, air cycle cooling, cold boxes, equipment cooling)

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 force, weight and couple, state the principle of moments and conditions for static equilibrium and solve two problems on simply supported beams, one that has three point loads and one that has three point loads and a uniformly distributed load [IE1, IE4]	**M1**	determine the shear stress in the rivets of a typical aircraft sheet metal riveted joint in both single and double shear and, from given appropriate values, find the factor of safety in operation in each case	**D1**	use the continuity equation and Bernoulli's theorem to determine, from given parameters, the flow rates, velocity and pressure changes that occur in the airflow as it passes through a convergent-divergent duct and compare these changes with those that take place in a closed section convergent-divergent wind tunnel
P2	define direct and shear stress and strain and elastic modulus, and solve three problems that involve finding direct and shear stress and strain and modulus [IE1, IE4]	**M2**	find the required parameters for two problems involving aircraft linear motion, thrust and power	**D2**	compare the principles, operation and relative merits of two different aircraft cooling systems.
P3	for an aircraft treated as a simply supported beam in static equilibrium, determine the centre of gravity from a datum, given the reactions and distances of the aircraft wheels from this datum [IE1, IE4]	**M3**	define centripetal acceleration, centripetal force, inertia force, torque and banking angle and determine the required kinetic and dynamic parameters for an aircraft subject to two different types of manoeuvre		
P4	define Newton's laws of motion, linear motion and motion under gravity and solve two problems on linear motion with constant acceleration and one problem on motion under gravity [IE1, IE4]	**M4**	using a P-V diagram and a T-S diagram, sketch and label the ideal and practical cycles for a reciprocating piston engine and a gas turbine generator and explain the main features and differences of each of these cycles.		

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:**
P5 define periodic motion, simple harmonic motion and resonance and explain how resonance occurs and its possible effects on periodic motion systems [IE1, IE4]		
P6 define load, effort, mechanical advantage, velocity ratio and efficiency and solve two problems on lifting machines that involve these parameters [IE1, IE4]		
P7 define frictional force, coefficient of friction, dynamic friction and static friction and solve two problems on friction that involve these parameters [IE1, IE4]		
P8 define and solve one problem for each of mechanical work, potential energy, kinetic energy and power [IE1, IE4]		
P9 define viscosity, incompressible flow and transition point, and explain how compressibility affects the nature of airflow with increase in airspeed [IE1, IE4]		
P10 explain the nature of the boundary layer and its effect on fluid flow over an aerofoil		
P11 explain how Reynolds equations may be used to determine whether, for internal piped flow and external aerofoil flow, the fluid is laminar or turbulent		
P12 solve two fluid flow problems that involve the use of the continuity equation for volume and mass flow, respectively [IE1, IE4]		

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:**
P13 define the fundamental thermodynamic parameters and explain how heat is transferred by conduction, convection and radiation [IE1, IE4]		
P14 solve three problems involving temperature conversion between Kelvin, Celsius and Fahrenheit, respectively [IE1, IE4]		
P15 solve four problems involving latent heat, linear thermal expansion, thermal energy and thermal power respectively		
P16 solve four thermodynamic problems that require the use of Boyle's law, Charles' law, the combined gas law and the characteristic gas equation, respectively [IE1, IE4]		
P17 describe the heat ranges for the use of mercury thermometers, alcohol thermometers and optical pyrometers and give one example where pyrometers may be used for temperature measurement on aircraft.		

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

The learning outcomes have been written so that they may be delivered in the order presented. Learners often find the scientific concepts presented in this unit difficult, particularly those concerned with dynamics, fluids and thermodynamics. Tutors should therefore be aware that additional time might be necessary to successfully deliver learning outcomes 2, 3 and 4.

When delivering learning outcome 1, learners need to be made aware of the relationship between force, mass, weight and pressure, as well as an understanding of how to represent forces as vectors and resolve vector systems. Emphasis should also be placed on the relationship between the loading of a simply supported beam and that of the aircraft fuselage, where the supports may represent the aircraft wheels. This theory can then be applied to aircraft weight and balance. The application of the principles concerned with stress and strain can be applied to examples involving aircraft structural loading and in particular to riveted and bolted joints. The use of laboratory beam apparatus and tensile testing of riveted joints would be a very good way to enhance understanding.

When delivering the kinetic and dynamic parameters and mechanical principles in learning outcome 2, the relationship of Newton's laws to the linear equations of motion should be emphasised. These principles, together with those concerning thrust force and frictional resistance could then be applied to problems related to aircraft acceleration/retardation along a runway. Learners will need to be familiar with the principles of periodic motion, pendulum motion, simple harmonic motion and resonance and the effects of resonance on periodic systems. When delivering the content on mechanical machines, such as lifting jacks and winches, the mechanical advantage, velocity ratio and effects of frictional resistance on their efficiency should be highlighted. Also the content concerned with centripetal acceleration, centripetal force, inertia force, torque and other dynamic parameters for aircraft during manoeuvres, needs to be well understood. The use of laboratory apparatus such as pendulums, screw jacks and centripetal force apparatus would be a good means of enhancing these areas of the unit content.

When delivering the parameters associated with learning outcome 3, emphasis should be placed on those associated with fluid density, viscosity and their relationship to compressible and incompressible flows and compressibility effects. The formation of the boundary layer and transition point movement, together with the use of Reynolds numbers to ascertain laminar or turbulent flow, should also be emphasised. When delivering the principles elements of this learning outcome, the use of both forms of the continuity equation and Bernoulli's theorem should be covered in some detail. At this stage, laboratory work using apparatus could be undertaken by learners to aid understanding of the continuity equation and Bernoulli principle and their applications.

When delivering learning outcome 4, tutors are advised to spend as much time as possible covering the parameters detailed in the unit content, since most of these are needed for an understanding of the thermodynamic principles and aircraft applications that follow. Emphasis should be placed on temperature systems, specific heat, thermal expansion, latent heat, thermal energy and thermal power as well as the three methods used to transfer heat.

Tutors should ensure that learners understand the nature and use of the gas laws and the characteristic gas equation, as well as being able to define and differentiate between open and closed thermodynamic systems. Learners will need to have a basic qualitative understanding of the first and second law of thermodynamics and the relationship of the second law to the heat pump and to applications such as vapour cycle cooling and air cycle cooling. Tutors need also to ensure that learners have a basic understanding of polytropic, adiabatic and isentropic processes and P-V, T-S diagrams.

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 unit content, scheme of work and assessment strategy • explain force, the mass/weight relationship, pressure, vector representation of forces, couples and static pressure • tutor demonstration using laboratory force board apparatus, to show how using vector drawing, forces may be resolved • explain simply supported beams, the principle of moments and the conditions for static equilibrium, using beam apparatus • explain the application of beam theory to aircraft static loading and determination of parameters such as, aircraft centre of gravity and reactions at wheels. *Individual learner activities*: • exercises on solving problems on forces, couples and pressure • use laboratory beam apparatus to determine parameters and complete tutor-led class work exercises on beams and their application. *Whole-class teaching:* • explain direct stress and strain, shear stress and strain, the tensile modulus and shear module, their relationship and the application of this theory to aircraft structures and fastened joints. *Individual learner activities*: • exercises on finding parameters for stress, strain and modulus • laboratory exercises using equipment (such as, Hook's apparatus and tensile testers) to determine parameters for problems on aircraft weight and balance and riveted joints.
Prepare for and carry out **Assignment 1: Force, Stress Mechanical Principles and Static Aircraft Engineering Systems** (P1, P2, P3, M1).
Whole-class teaching: • explain linear, circular and periodic motion parameters and mechanical principles including Newton's laws, linear equations of motion, forces due to linear motion, circular/angular motion and forces due to angular motion. *Individual learner activities*: • carry out experiments/exercises on linear and angular motion using eg distance/time devices, centripetal acceleration/force apparatus. Tutor-led exercises on problems associated with linear and angular motion and forces due to motion. *Whole-class teaching:* • describe and demonstrate lifting machine parameters and types, friction, mechanical work, energy and power. *Individual learner activities*: • carry out experiments/exercises on differing machines (such as wheel and axle, screw jack, pulley systems) to determine parameters eg velocity ratio, load, effort, mechanical advantage, friction losses, efficiency, power output. Tutor-led problem solving sessions on machines, mechanical work, energy, power and friction.

Topic and suggested assignments/activities and/assessment
Whole-class teaching: • in a formal classroom or preferably an aircraft engineering environment on the application of kinetic and dynamic theory eg aircraft motion, engine thrust, rotating machines, aircraft manoeuvres, lifting systems. *Individual learner activities*: • practical investigations and tutor-led problem solving sessions on aircraft applications of kinetic and dynamic theory.
Prepare for and carry out **Assignment 2: Kinetic and Dynamic, Parameters, Principles and Systems** (P4, P5, P6, P7, P8, M2, M3).
Whole-class teaching: • using laboratory facilities, explain fluid flow parameters and principles eg fluid pressure, velocity, density, viscosity, different types of flow, boundary layer, Reynolds number and its use to determine laminar or turbulent flow, equations and their use (such as continuity, Bernoulli and Reynolds). *Group activities*: • group practical investigations using laboratory apparatus (such as Bernoulli, Venturi, Flow rate measuring equipment) and tutor-led problem solving sessions on fluid parameters and principles. *Whole-class teaching:* • using laboratory facilities, explain the application of fluid principles to aircraft fluid flow eg flow through ducts, flow over aerofoil surfaces. Determination of parameters (such as velocity, density, mass/volume flow rates, laminar or turbulent flow). *Individual learner activities*: • problems associated with the application of fluid principles to aircraft fluid flows.
Prepare for and carry out **Assignment 3: Parameters, Principles and Aircraft Fluid Flows** (P9, P10, P11, D1).
Whole-class teaching: • explain fundamental parameters eg temperature, thermal energy, thermal power, thermal expansion, latent heat, heat transfer, heat capacity, thermodynamic processes • in laboratory/engineering classroom, explain the ideal gas laws, governing laws and processes (such as first law, second law, open and closed systems, thermodynamic processes and their representation on P-V and T-S diagrams) • explain aircraft thermodynamic systems (such as temperature measurement, piston engine cycles, gas turbine engine cycles, cooling systems) using a practical aircraft engineering environment. *Individual learner activities*: • tutor-led exercises on thermodynamic parameters • tutor-led exercises on thermodynamic laws and processes • tutor-led problem solving sessions and/or an assignment on aircraft thermodynamic systems.
Prepare for and carry out **Assignment 4: Thermodynamic Parameters, Principles and Aircraft Systems** (P12, P13, P14, P15, M4, D2).
Feedback on assessment and unit evaluation.

Assessment

Four assignments could be used for the assessment of this unit. Evidence may be gathered from written responses to formal timed assignments and should also be gathered from laboratory reports and reports resulting from learner-led investigations wherever possible.

The first assignment is likely to consist of a practical laboratory-based task plus formal written test. Learners must be able to define the basic parameters of force, weight, couple, principle of moments and the conditions for static equilibrium as well as solve problems on simply supported beams with varying loads (P1). They must define direct and shear, stress and strain and the tensile and shear modulus and solve a number of problems on stress, strain and the elastic modulus (P2). Evidence for these two criteria will probably be in the form of a written report based on learners' practical investigations. The written tasks, covering P3 and M1 will need to give learners an opportunity to determine the centre of gravity of an aircraft (P3) apply stress theory to aircraft riveted joints and determine stress parameters for these joints, given the appropriate data (M1).

The second assignment could also consist of a mixture of formal written tasks and laboratory-based investigations. The written tasks will need to ensure that learners define Newton's laws, linear motion and motion under gravity and solve related problems on them (P4). They must be able to define periodic motion, simple harmonic motion and resonance and explain how resonance occurs in systems subject to periodic motion (P5). They must understand the relationship between mechanical work, energy and power and be able to define them and solve problems using the equations that define them (P8). Further written tasks can then ask learners to find the parameters for problems involving aircraft linear motion, thrust force and power (M2). Learners will also need to define and use the concepts of centripetal acceleration, centripetal force, torque and banking angle, sufficiently to be able to, where appropriate, to find the required parameters for two different types of aircraft manoeuvre (M3).

A practical task can also be used as part of the second assignment which requires learners to investigate machine parameters and solve problems on machines that involve finding these parameters (P6). Learners also investigate the nature of friction, in particular the relationship between friction force and the coefficient of friction as well as knowing the difference between dynamic and static friction and solving problems that involve finding friction parameters (P7).

The third assignment is likely to consist of a formal written test. This should require learners to define viscosity, incompressible flow and transition point and explain how compressibility affects the nature of the airflow with increasing airspeed (P9). They must explain the nature of the boundary layer and its effect on the airflow over an aerofoil (P10), as well as being able to explain the nature and use of Reynolds equations to determine the laminar or turbulent nature of the airflow (P11). They must also use the continuity equation to solve problems for mass and volume flow (P12). A further task should require learners to use the continuity equation and Bernoulli's theorem to determine the changes in flow rates, velocities and pressure of the air as it passes through a convergent divergent duct. They should then compare these changes with those that take place as the airflow passes through a convergent-divergent wind tunnel (D1).

The final assignment can be a combination of written tasks and a practical-based investigation. The written tasks will need to give learners the opportunity to define thermodynamic temperature, specific heat capacity, thermal expansion, latent heat, thermal energy, thermal power, heat transfer by conduction, convection and radiation (P13). Learners will also need to solve problems associated with these parameters (P14 and P15). They must understand the gas laws (Boyles, Charles, combined) as well as the characteristic gas equation and be able to solve problems to obtain parameters, using these laws (P16). Learners must also understand the heat range and use of mercury thermometers, alcohol thermometers and optical pyrometers and be able to given an example of the aircraft use of an optical pyrometer (P17).

Learners should then carry out a practical investigation to determine the nature and use of pressure-volume and temperature-entropy diagrams and gather their evidence in a written report. Using a P-V diagram, learners will need to sketch and label the ideal constant volume cycle and practical four-stroke cycle. They will also need to use a T-S diagram to sketch and label the ideal constant pressure cycle and practical gas turbine generator cycle. Their report should include an explanation of the important features and differences of each of these cycles. Tutors should note that only a qualitative understanding of entropy is required, sufficient to be able to define and recognise reversible and non-reversible processes when sketching the cycles and explaining their differences. Learners must also compare and contrast the principles, operation and relative merits of two different aircraft cooling systems and produce a report on their findings (D2).

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, P3, M1	Force, Stress Mechanical Principles and Static Aircraft Engineering Systems	Two part assignment consisting of a practical laboratory investigation and formal written tasks requiring learners to respond to written questions.	A written report resulting from practical investigative laboratory work (P1, P2) and written response to set tasks, carried out under controlled conditions (P3, M1).
P4, P5, P6, P7, P8, M2, M3	Kinetic and Dynamic Parameters, Principles and Systems	Two part assignment consisting of a formal written part requiring learners to respond to written questions and a practical laboratory investigation.	Written response to set tasks, carried out under controlled conditions (P4, P5, P8, M2, M3) and a written report resulting from practical investigative laboratory work (P6, P7).
P9, P10, P11, D1	Parameters, Principles and Aircraft Fluid Flows	A formal assignment requiring learners to respond to written tasks.	Written response to set tasks, carried out under controlled conditions.
P12, P13, P14, P15, M4, D2	Thermodynamic Parameters, Principles and Aircraft Systems	Two part assignment consisting of a formal written part requiring learners to respond to written questions and an investigative assignment.	Written response to set tasks, carried out under controlled conditions (P12, P13, P14, P15) and a written report resulting from investigation (M4, D2).

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
		Principles and Applications of Aircraft Physical Science
		Theory of Flight
		Mathematics for Technicians

This unit has been mapped against the EASA Part-66 examinations and when taken with *Unit 66: Theory of Flight and Unit 68: Principles and Applications of Aircraft Physical Science* covers the knowledge requirements for Module 2 Physics.

The unit will also provide underpinning knowledge for many of the units in the SEMTA Level 3 National Occupational Standards in Aeronautical Engineering.

Essential resources

Learners will need to have access to a laboratory facility that is equipped with equipment such as force boards, beam apparatus, tensile tester, screw jacks, winches, pulley systems, friction apparatus, turntable apparatus, flow rate and velocity measuring apparatus and a Venturi meter.

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

Dingle L and Tooley M – *Aircraft Engineering Principles* (Butterworth-Heinemann, 2004) ISBN 075065015X

Tooley M and Dingle L – *BTEC National Engineering* (Newnes, 2007) ISBN 9780750685214

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 and evaluating information when solving problems relating to aircraft mechanical science.

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.

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 a range of problems relating to aircraft mechanical science
Select and apply a range of skills to find solutions	solving a range of problems relating to aircraft mechanical science
Use appropriate checking procedures and evaluate their effectiveness at each stage	solving a range of problems relating to aircraft mechanical science
Interpret and communicate solutions to practical problems in familiar and unfamiliar routine contexts and situations	solving a range of problems relating to aircraft mechanical science
English	
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	researching mechanical principles and their aircraft applications
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	producing written reports based ion practical investigations.