Unit 66: Theory of Flight

Unit code: A/600/7123

QCF Level 3: BTEC Nationals

Credit value: 10

Guided learning hours: 60

Aim and purpose

This unit will provide learners with an understanding of the atmosphere in which aircraft fly and the means by which lift is generated and drag is created.

Unit introduction

Large modern passenger aircraft can weigh in excess of five hundred thousand kilogrammes when they fly with a full fuel and passenger load, yet this combined mass is lifted into the air with apparent ease. Modern jet fighter aircraft can exceed the speed of sound and are very manoeuvrable. This unit will help learners understand how such aircraft fly and how they are controlled and stabilised.

The unit will provide learners with an understanding of aircraft flight principles, including the means by which aircraft are controlled, manoeuvred and stabilised. In addition, the particular problems associated with aircraft that fly close to the speed of sound (transonic range) will also be investigated.

Learners will develop an understanding of the atmosphere in which aircraft fly and the importance of the International Standard Atmosphere, in setting standard values for comparing aircraft performance. The nature of subsonic airflow over aerodynamic sections and over the aircraft at large will be considered, including the forces that result from such airflow and the effect these forces have on the aircraft, during steady flight and during manoeuvres.

How aircraft are controlled and stabilised is looked at in some depth. A qualitative treatment of static and dynamic stability, together with a brief look at the design features that enhance stability, will provide learners with a suitable introduction to the fundamental concepts associated with aircraft stability. A range of flight controls and lift augmentation devices are considered and the way in which they affect control about the aircraft axes is also covered.

Finally, when considering high speed flight, the effects created by the air flowing over the aircraft at high subsonic, transonic and supersonic speeds are covered in some detail, together with the design features required to assist aircraft to fly safely in and through the transonic range.

Learning outcomes

On completion of this unit a learner should:

1. Understand the nature, physical parameters and use of the International Standard Atmosphere (ISA) and subsonic airflow over aerofoil sections
2. Understand the generation and interaction of aircraft lift and drag forces
3. Understand aircraft stability and control
4. Understand the nature of subsonic, transonic and supersonic airflow.

Unit content

1 Understand the nature, physical parameters and use of the International Standard Atmosphere (ISA) and subsonic airflow over aerofoil sections

Nature and use of the ISA: use (basis for comparison, engine performance parameters, instrument calibration); zones (troposphere, stratosphere, chemosphere); temperature and pressure variation with altitude; significance of tropopause and stratopause

ISA parameters: standard values, definitions and changes with altitude (temperature, barometric pressure, atmospheric pressure, static pressure, density, density ratio, acceleration due to gravity, temperature lapse rate, dynamic viscosity, speed of sound, tropopause, stratopause)

Nature and parameters of subsonic flow: flow over a flat plate, streamline, laminar and turbulent flow; dynamic and kinematic viscosity of air

Aerofoils, wings and airflow: terminology (aerofoil profile, camber, mean camber, high camber, chord line, leading and trailing edge, angle of incidence (AOI), angle of attack (AOA), thickness/chord ratio, fineness ratio; airflow and airflow parameters over aerofoil sections/wings (boundary layer, boundary layer separation, transition point, free stream flow, relative airflow, upwash and downwash, stagnation point, centre of pressure, wing shape, aspect ratio, vortices)

2 Understand the generation and interaction of aircraft lift and drag forces

Lift and drag force generation: Bernoulli and Venturi principles and their relationship to lift force generation; factors affecting lift (aerofoil shape, lift coefficient, angle of attack, air density, airspeed, stall); drag types (total drag, induced drag, profile drag (skin friction, form, interference)); factors affecting drag (aerofoil shape, angle of attack, streamlining, drag coefficient, airspeed, ice accretion (such as hoar frost, rim ice, glaze ice, changing altitude))

Lift and drag interaction: eg lift and drag plots, aerofoil efficiency (the lift to drag ratio (L/D), polar plot and optimum AOI, coefficients of lift and drag, minimum drag, pitching moment

Basic forces, flight couples and their interaction: lift, weight, thrust, drag; flight couples (lift/weight, thrust/drag); action of forces and force couples in straight and level flight

Manoeuvre loads and flight envelopes: manoeuvre types and loads/forces imposed eg roll, pitch, yaw, climb, cruise, glide, dive, level steady turn, pullout from a dive; definition and significance of load factor and flight envelopes eg manoeuvre, gust, operating strength limitations, design speeds, angle of attack position and stall conditions

3 Understand aircraft stability and control

Aircraft stability: nature of stability (stable, unstable, neutrally stable, static and dynamic stability, response to a disturbance); aircraft stability (lateral, longitudinal and directional)

Methods of improving stability: lateral stability eg wing dihedral, sweepback, high wing position, keel surface, yaw dampers; longitudinal stability eg tailplane (horizontal stabiliser) size and position, elevator movement; directional stability eg fin, keel surface aft of centre of gravity

Purpose and operation of control surfaces: primary controls (ailerons, elevators, rudder); secondary controls eg canards, stabilisers, stabilators, elevons, tailerons, flaperons; tabs eg trim, aerodynamic balance and anti-balance, balance panels, servo, spring, mass balance

Purpose and operation of lift augmentation devices: eg plain, split, slotted, double slotted, fowler, multi-slotted fowler, Krueger, slots, slats, vortex generators, wing fences, winglets

Purpose and operation of drag inducing devices: spoilers (lift/dump and roll), airbrakes

4 Understand, the nature of subsonic, transonic and supersonic airflow

Subsonic airflow: incompressible flow, boundary layer thickening and separation, centre of pressure forward, turbulence, reduction in velocity rear of surface, normal stall

Transonic airflow: eg compressible flow, transonic range, speed of sound, Mach number, critical Mach number, formation of shockwave, shock stall, flow through shockwave, sonic bang

Supersonic airflow: eg high speed wing sections, increase in velocity and reduction in pressure at rear of surface, centre of pressure movement, trim change, kinetic heating, flow through high speed intakes

Problems and design factors in transonic range: problems eg density and pressure rise, velocity fall, pitching, buffeting, shock stall, loss of control effectiveness; design factors to alleviate problems eg low camber and high speed aerofoil sections, washout, wash-in, area ruling, vortex generators, blown air, sweepback, wing fences

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 the nature and use of the International Standard Atmosphere and define the parameters and their standard values in such an atmosphere	**M1**	explain how profile and induced drag vary with airspeed and illustrate, using a drag/airspeed plot, when minimum drag is achieved	**D1**	using vector diagrams, explain how lateral stability may be improved by sweepback and how the aircraft tailplane helps restore the aircraft after it has been subject to a pitching moment disturbance
P2	describe and define laminar and turbulent flow and explain the nature of dynamic and kinematic viscosity of air	**M2**	construct a vector force diagram, showing the interaction of the forces acting on an aircraft in a steady turn and explain how the aircraft is held into the turn	**D2**	explain how high speed aerofoil sections, area ruling and sweepback is used to reduce the problems when aircraft fly in the transonic range
P3	define all terminology and parameters associated with subsonic airflow over aerofoil sections and aircraft wings	**M3**	explain the operation and give the relative advantages of canard fore planes and taileron and flaperon controls	**D3**	explain how highspeed intake design is used to ensure the correct airflow to the engine during subsonic and supersonic flight.
P4	explain the Bernoulli and Venturi principles and their relationship to the generation of lift and the factors that affect lift generation over aircraft	**M4**	give reasons for installing flying control trim tabs and balance tabs and explain their mechanical/aerodynamic operation from control column to tab		
P5	describe the types of drag and explain the factors that affect drag forces and enable the best lift/drag ratio to be achieved	**M5**	define the speed of sound, Mach number and critical Mach number and explain why Mach number is used as the measure of airspeed on high-speed aircraft.		
P6	explain how lift, weight, thrust and drag forces are combined and how these combined couples react to sustain straight and level flight				

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:**
P7 sketch and label a force diagram for an aircraft in cruise and in a steady turn and for a given manoeuvre envelope diagram, identify its parameters and explain their significance [IE1, IE4]		
P8 explain the nature of static and dynamic stability and sketch the response to a disturbance of an aircraft that is statically stable and dynamically unstable		
P9 describe one method for improving aircraft lateral stability, longitudinal stability and directional stability		
P10 state the purpose and explain the operation of primary controls, trim tabs, elevons, split flaps, fowler flaps and airbrakes		
P11 explain the nature of subsonic airflow over low-speed wing sections for both normal and stall conditions, with the aid of suitable sketches [IE1, IE4]		
P12 explain how during transonic flight the shockwave is first formed over the aircraft wing surface and describe the effects on the airflow either side of the shockwave		
P13 explain why the centre of pressure moves forward when an aircraft flies from transonic to supersonic speed		
P14 explain why there is a loss of control effectiveness when an aircraft flies in the transonic range and describe one design feature that helps to alleviate this problem.		

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

This unit has been designed to cover the elementary flight theory needed by all those wishing to enter the aerospace industry at technician level, irrespective of their chosen field of specialisation. Elements of the content of this unit will act as a crucial foundation for further study of both mechanical and avionic units.

Centres could deliver this unit early in the first year of the programme, providing an aeronautical flavour at an early stage. Learners will need to have been introduced to the concepts of force, pressure and density. They should also have sufficient analytical ability to understand flight forces, couples and manoeuvre loads, as well as have an idea of vector quantities and their representation. However, tutors should also note that one of the primary aims of this unit is to deliver the subject matter in a qualitative rather than quantitative way, thus understanding of the principles involved should be emphasised, rather than a purely formulaic approach being adopted, as may have been the case in the past.

The learning outcomes are best delivered in order, with approximately equal weighting being applied to each. In learning outcome 1 the effect that atmospheric parameters have on the generation of lift and drag with rising altitude should be explained and learners should know, in particular, the purpose of the ISA and the standard sea-level values for temperature, pressure and air density in the ISA. When delivering the topics associated with the nature of subsonic flow, learning would be enhanced with some form of visual display of turbulent and laminar airflow as well as, a practical demonstration of the flow of low and high viscosity fluids. In addition to defining the terminology associated with aerofoil sections, learners should also attain a thorough understanding of the nature and parameters associated with subsonic airflow over these sections and over aircraft wings, this should be kept in mind by tutors when delivering this topic.

Wherever possible the delivery of the topics in learning outcome 2 would be greatly enhanced by practical demonstrations and/or direct learner participation in practical/laboratory exercises. It is appreciated that some centres may not have all the desired equipment, so the assessment strategy for this unit has been designed to allow for this. So, for example, when delivering the topics associated with the generation of lift and drag forces, alternative theoretical whole-class teaching using videos or similar may be used instead of, or in addition to, experimental/practical work. Although, the equipment necessary for determining basic flight force parameters could be designed to involve the use of some relatively simple apparatus such as a blower, capable of moving air up to but not necessarily above 25 ms^{-1}. The lift and drag balances needed with the blower are mechanical and both lift and drag forces can be measured by counter balancing a simple aerofoil surface with weights on a scale pan.

When delivering the content associated with aircraft stability in learning outcome 3, a clear distinction should be made between static and dynamic stability and the response motions after a disturbance should be known. The more difficult dynamic concepts may be limited to a qualitative explanation of Dutch role, phugoid motion and porpoising, which can best be demonstrated using a model aircraft. The conventional methods for improving lateral, longitudinal and directional stability should also be emphasised. When delivering the control aspects of learning outcome 3 the purpose and operation of primary manual flight controls (ailerons, elevators, rudder) should be thoroughly understood, as well as a range of secondary controls, tabs, lift augmentation devices and drag inducing devices. The principles of operation of many of these controls may be best demonstrated using a variety of appropriately rigged aircraft models and/or purpose built training aids. The operation of the more sophisticated lift augmentation and drag inducing devices may best be demonstrated using appropriate video material or watching a demonstration on a training aircraft, when these devices are being operated.

The behavioural aspects of subsonic airflow in learning outcome 4, may have been covered in part during the delivery of learning outcome 1, however, at this stage and as a prelude to high speed flight, the behaviour of subsonic airflow as it travels over an aircraft wing cross-section should be emphasised, so that comparisons can be made with truly supersonic airflow, where the airflow behaves in an almost opposite manner. A large proportion of the delivery time should be concerned with the behaviour of the airflow over the aircraft while flying in the transonic range. Where during this range the shockwave is first formed and the incumbent problems associated with the airflow travelling through the shockwave are first meet. The various design factors devised to overcome or reduce these problems should also be thoroughly covered, with the delivery of this subject matter being enhanced by showing video footage/photographs of the design of a variety of high-speed aircraft.

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 the need and describe the nature and parameters of the ISA and indicate the changes in the ISA and real atmospheres, with increase in altitude from ground level • familiarise learners with standard sea level values of important ISA parameters. Individual learner activity: • multiple choice quiz on the nature of the atmosphere and the ISA.
Whole-class teaching: • tutor demonstration using smoke generator to show streamlines, laminar and turbulent airflow over flat plate, aerofoil cross-section and sphere (or similar), at different angles to the airflow • explain the dynamic and kinetic viscosity of air and to understand the difference between them • using aerofoil and aircraft models identify and define the terms used for aerofoil sections, including the angles of incidence and attack • tutor demonstration using smoke tunnel and wind-tunnel or wind generator plus aerofoil sections and aircraft models to identify and understand the nature of airflow and airflow parameters over aerofoil section and aircraft wings. *Practical learner activity:* • carry out practical activities using available smoke tunnel and wind tunnel apparatus and record and comment on observations.
Prepare for and carry out **Assignment 1: The ISA and Subsonic Airflow Over Aerofoil Sections** (P1, P2, P3)

Topic and suggested assignments/activities and/assessment
Whole-class teaching: • explain the relationship between aerofoil shape, lift/drag coefficients, angle of attack, air density and speed, ice accretion and wing stall on the generation of lift and drag. *Individual learner activity:* • multiple choice quiz on lift and drag force. *Whole-class teaching:* • explain lift/drag plots and their significance, interaction of flight forces and couples (lift, weight, thrust and drag). *Individual/group activity:* • carry out wind-tunnel experiment/s using appropriate models to assess the interaction between lift and drag and determine the factors. *Whole-class teaching:* • explain the types of load imposed on aircraft during all stages of flight and the significance of load factor and the nature of flight envelopes. *Small-group activity:* • using specialist aircraft manuals/training material, investigate the nature and reinforce the factors associated with aircraft flight manoeuvre and gust envelopes.
Prepare for and carry out **Assignment 2: Flight Forces, Manoeuvre Loads and Flight Envelopes** (P4, P5, P6, P7, M1, M2)
Whole-class teaching: • using appropriate modes/training aids, explain the nature of the various forms of static and dynamic stability and the response of the aircraft to combination of these stabilities, together with the various methods for improving lateral, longitudinal and directional stability. *Individual activity:* • multiple-choice quiz on aircraft stability. *Whole-class teaching:* • using appropriate models and training rigs to explain the purpose and operation of primary and secondary controls, tabs, lift augmentation and drag inducing devices. *Individual/small group activity:* • investigation into the operation of a variety of aircraft controls and devices.
Prepare for and carry out **Assignment 3: Stability and Control** (P8, P9, P10, M3, M4, D1)
Whole-class teaching: • explain the nature and behaviour of airflow over the aircraft with increasing velocity (from subsonic, then through the transonic range to truly supersonic), including the formation of the shockwave and the consequent adverse effects on aircraft performance as the air passes through the shock wave • explain the problems associated with aircraft as they fly in the transonic range and the design features used to reduce the time and alleviate the problems in this range. *Individual activity:* • multiple-choice quiz on high-speed flight.
Prepare for and carry out **Assignment 4: High Speed Flight** (P11, P12, P13, P14, M5, D3)
Feedback on assessment and unit evaluation.

Assessment

It is expected that a range of assessment methods will be used for this unit. Evidence may be gathered from written responses to assignments and formal timed assessments. Evidence from laboratory reports and observation records may also be appropriate, particularly when assessing parts of learning outcomes 1 and 2. A suggested assessment plan is given above where the 4 assessment activities cover each of the outcomes. The assessment plan, should wherever appropriate endeavour to provide a practical/laboratory method for gathering assessment evidence, although from the assessment plan, it can be seen that there is sufficient flexibility built-in, to be able to leave the design and number of these practical activities to the discretion of the centre.

To achieve a pass grade learners must understand the need and make-up of the ISA and be able to define the sea-level values particularly for, pressure, temperature and density and also know how they change with altitude (P1). They must be able to define and describe laminar and turbulent flow and explain the nature of dynamic and kinematic viscosity, in a qualitative way (P2). In the last topic necessary to achieve learning outcome 1 learners must provide evidence that they are fully conversant with the terminology associated with aerofoil sections and that they understand the effects on the airflow as it flows over these sections. In particular they need to understand the relationship between lift, drag, velocity and angle of attack, as well as an understanding of the creation and effects of wing tip vortices (P3).

For learning outcome 2 learners must first be able to explain the Bernoulli and Venturi principles and their relationship to the generation of lift (P4). They need to be able to describe the different types of drag, the factors that affect drag over the whole airframe and the factors that enable the most efficient lift/drag ratio to be achieved (P5). They must describe the four basic forces that act on the aircraft and explain the action of the combined drag couples necessary to sustain level flight (P6). Learners must be able to sketch and label a force diagram for an aircraft in cruise and in a steady turn and explain quantitatively their interaction. For a given manoeuvre envelope, learners need to be able to identify the different parameters and label them on the given diagram as well as explaining their significance, with respect to the aircraft's performance (P7).

A third assignment could cover learning outcome 3. For P8 learners need to demonstrate an understanding of the static and dynamic behaviour of an aircraft after being subject to a disturbance. This will require learners to provide a basic definition for static stability and dynamic stability. They will also need to produce sketches to show an aircraft's motion after a disturbance, based on whether or not the aircraft is dynamically stable or dynamically unstable. In the latter case learners need just show this situation as a diverging sinusoidal wave motion and have knowledge of phugoid, porpoising and Dutch role motion.

Learners must be able to describe the conventional methods for improving lateral, longitudinal and directional stability, these will include but not be limited to, the use of anhedral, the tail plane and keel surface aft of the centre of gravity (P9). They must be able to state the purpose and explain the operation of manual primary controls (ailerons, tailplane, rudder) from movement at the control column to the action at the control surface. In addition learners need to state the purpose and explain the operation of a variety of secondary controls, lift augmentation devices and drag inducing devices (P10). Evidence for the achievement of P10 might best be obtained from a theoretical assignment, where sketches and written responses can be gathered.

To achieve P11, learners are required to be able to explain the effects of airflow over an aerofoil section when the air is travelling initially at subsonic speed. They then need to explain how the shockwave is first formed and the effects the shockwave has on the airflow (and subsequently on the aircraft) as the airflow passes through it (P12). They must be aware of the problems encountered by the aircraft, as it flies through the transonic range, such as loss of control effectiveness and the design feature/s that may be used to alleviate this problem (P14). Learners then need to thoroughly understand how the behaviour of the airflow changes as the aircraft accelerates through the subsonic, transonic and truly supersonic speeds ranges and the effect these changes have on the handling and performance of the aircraft, particularly when flying in the supersonic range (P13). Evidence for P11 to P14 might best be gathered from the responses to written questions.

To achieve a merit grade, learners need to build on their understanding of lift and drag plots and flight forces. Evidence of achievement for M1 and M2 could come from the response to written tasks as part of assignment 2.

For M3, learners need to explain the operation of specific secondary controls (canard fore planes, tailerons and flaperons), To achieve M4 they need to explain the action and operation of balance tabs and trim tabs (from control column to tab) and their effect on aircraft control. M3 and M4 can be assessed as part of assignment 3.

To achieve M5, learners need to define the speed of sound, Mach number and critical Mach number and explain why Mach number is used as the measure of airspeed on high-speed aircraft. Evidence of achievement of M5 may be obtained from the written report submitted after learners have carried out their theoretical investigation for assignment 4.

To achieve a distinction grade, learners must use vector diagrams to explain how lateral stability may be improved by sweepback and how restoring forces acting on the tail plane help return the aircraft to a stable position after a pitching moment disturbance (D1). To achieve D2 learners will need to explain how high-speed aerofoil sections, area ruling and sweepback are used to reduce the problems when aircraft fly in the transonic range. They must also explain how high speed intake design is used to ensure the correct airflow to the engine during subsonic and supersonic flight (D3). Evidence of achievement of D1, D2 and D3 may be obtained from the written responses to tasks in assignments 3 and 4.

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	The ISA and Subsonic Airflow Over Aerofoil Sections	A formal assignment requiring learners to respond to written tasks.	Written responses to set written tasks carried out under controlled conditions.
P4, P5, P6, P7, M1, M2	Flight Forces, Manoeuvre Loads and Flight Envelopes	A formal assignment requiring learners to respond to written tasks.	Written responses to set written tasks carried out under controlled conditions.
P8, P9, P10, M3, M4, D1	Stability and Control	A formal assignment requiring learners to respond to written tasks.	Written responses to set written tasks on stability and control, as per grading criteria, carried out under controlled conditions.
P11, P12, P13, P14, M5, D2, D3	High Speed Flight	A two-part activity, requiring learners to first provide a written response to theoretical tasks. A second part requiring learners to carry out an investigation.	Written response to set questions covering the pass criteria P11 to P14, carried out under controlled conditions. A written report providing evidence of achievement of M5, D2, D3 criteria.

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 Aeronautical Mechanical Science

Essential resources

Ideally centres will have, or be able to provide access to the following:

- aircraft models, aerofoil cross-sections
- wind generators, simple sections and appropriate lift and drag balances
- some form of smoke generation or other visualisation equipment
- training aids, aircraft airframe components, flying control rigs
- flight theory videos/photographs.

In addition, learning would be enhanced if there was access to an open-wind tunnel complete with simple measuring equipment such as manometers, manual lift and drag balances.

Interpreting sophisticated digital read out equipment and converting these readings into force measurements, tends to have little meaning for learners at this stage.

Employer engagement and vocational contexts

Centres who have partnerships with employers and other educational establishments may be in a position to take advantage of the use of any resources they may have related to the delivery of theory of flight and aerodynamics. Employers may be also able to provide learners with access to aircraft where aerodynamic design features and flight controls may be viewed first hand and the operation of flight controls observed.

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

Barnard R and Philpott D – *Aircraft Flight: A Description of the Physical Principles of Aircraft Flight* (Prentice Hall, 2003) ISBN 0131200437

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

Kermode A, Barnard R and Philpott D – *Mechanics of Flight, 11th Edition* (Prentice Hall, 2006) ISBN 1405823593

Journal

Aerospace International published by the Royal Aeronautical Society (monthly)

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 when sketching force diagrams.

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	determining lift and drag and preparing to carry out wind-tunnel testing modifying and plotting data and drawing force diagrams
Select and apply a range of skills to find solutions	determining lift and drag and preparing to carry out wind-tunnel testing modifying and plotting data and drawing force diagrams
English	
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	researching and investigating the theory of flight
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	explaining the nature and use of the ISA explaining the Bernoulli and Venturi principles explaining the factors that affect drag forces.