

Unit 91: Principles of Helicopter Flight and Aerodynamics

Unit code:	A/600/7347
QCF Level 3:	BTEC Nationals
Credit value:	10
Guided learning hours:	60

● Aim and purpose

This unit will develop learners' knowledge and understanding of the principles of helicopter flight and will give them an understanding of how it is controlled.

● Unit introduction

The usefulness of the helicopter lies in its ability to take off and land vertically on almost any terrain, to hover stationary relative to the ground, and to fly forward, backward or sideways. These unique flying characteristics, however, come at a price, including complex aerodynamic problems, significant vibration, high levels of noise, and relatively large power requirements compared to fixed wing aircraft of the same weight.

This unit will introduce learners to the aerodynamic principles of helicopter flight and will develop their knowledge and understanding of the set-up and maintenance of flight surfaces and how they interact for control and stability during flight.

This unit will be of benefit not only to learners studying at BTEC National level, but also those following an apprenticeship in helicopter manufacture or maintenance, as well as those undergoing aircraft training with the armed forces.

● Learning outcomes

On completion of this unit a learner should:

- 1 Understand the constitution and behaviour of the part of the atmosphere in which flight takes place
- 2 Understand aerodynamic principles and lift generation by an aerofoil section
- 3 Know about helicopter flight and how control is obtained
- 4 Know about helicopter vibration and main and tail rotor tracking and balancing techniques.

Unit content

1 Understand the constitution and behaviour of the part of the atmosphere in which flight takes place

Constitution: the gases that make up the atmosphere and their quantities in the troposphere and stratosphere; atmospheric pressure at sea level

Behaviour: density, pressure and temperature variations with altitude, season and location; International Standard Atmosphere and reasons for its use; equations for pressure, density and temperature

2 Understand aerodynamic principles and lift generation by an aerofoil section

Aerodynamic principles: lift, drag, thrust and weight; airflow around an aerofoil; boundary layers; pressure distribution around an aerofoil; Bernoulli's theorem; Newton's laws of motion; anatomy of an aerofoil section; technical description of main rotor blade

Lift generation: angle of attack; angle of zero lift; stalling angle; optimum angle of attack; lift drag ratio; formulae for lift and drag

3 Know about helicopter flight and how control is obtained

Helicopter flight: eg modes of flight (vertical, lateral, fore and aft, hover, spot turns), coning angle, autorotation, vortex ring state, translating tendency, Coriolis effect, translational lift, dissymmetry of lift, gyroscopic precession

Control: main rotor disc, collective and cyclic controls; tail rotor; yaw control; main rotor head control eg swash plate, spider arm; effect of control movement

4 Know about helicopter vibration and main and tail rotor tracking and balancing techniques

Helicopter vibration: low, medium and high frequency vibration orders; main rotor vibration; tail rotor vibration; transmission vibration; static and dynamic main rotor balancing techniques; main rotor tracking; vibration analysis; vibration planes; lateral, vertical, fore and aft; monitoring equipment eg accelerometers, magnetic pick up, phasor box, computer

Tracking and balancing techniques: static balancing; dynamic balancing; balance weights; balance points; tracking of main blades eg brush and chalk/oil tracking, flag tracking, strobe tracking, passive tracking systems; tracking adjustments eg track rod, trim tab, weight strip

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 state the gases that make up the atmosphere and their quantities	M1 carry out calculations to ascertain pressure, density and temperature at three differing altitudes	D1 analyse a helicopter tracking report and make recommendations for corrective actions using the aircraft manual or the tracking equipment manual
P2 state the International Standard Atmosphere and explain the reason for its use and describe the relationship between pressure, density and temperature	M2 show how lift and drag vary for different angles of attack and find the optimum angle of attack for a given aerofoil	D2 interpret a vibration test on a helicopter and correctly identify the main vibration orders and their magnitudes and make recommendations for any corrective maintenance.
P3 explain the generation of lift and drag by an aerofoil section with reference to Bernoulli's theorem and Newton's laws	M3 describe translating tendency, Coriolis effect and dissymmetry of lift and state how they are controlled	
P4 describe a main rotor blade in technical terms	M4 explain how and where vibration monitoring equipment is fitted to a helicopter.	
P5 apply the principles of lift generation to carry out simple calculations to determine lift and drag on an aerofoil [IE1]		
P6 describe the modes of flight that are possible in a helicopter		
P7 state the purpose of the three helicopter flight controls and how they affect their respective rotor blades		
P8 describe how main rotors are arranged to compensate for gyroscopic precession		

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:
P9 describe the planes of vibration and the orders of vibration found on a helicopter		
P10 state the purpose of helicopter blade tracking and balancing, outline its importance and how adjustments are made.		

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 CT – creative thinkers	RL – reflective learners TW – team workers	SM – self-managers EP – effective participators
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Essential guidance for tutors

Delivery

This unit can be delivered using a range of lectures, tutor-led demonstrations, case studies, assignments, visits to aircraft factories and practical collection of data. Tutors should ensure that learners have a good understanding of the basic theory of flight, before moving on to the way that a helicopter flies and the problems associated with helicopter flight and tracking, balancing and vibration. A helicopter rotating system should be available and should be sufficiently complex to allow learners to carry out practical work on the system.

Learners will require instruction on how to use tracking and balancing equipment and vibration analysis equipment. They will also require instruction in the use of and access to aircraft documentation and manuals to enable them to carry out practical work on a helicopter. Tutors should encourage an investigative approach throughout.

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 formation and constituent gases of the atmosphere and the differences between troposphere and stratosphere
- explain atmospheric pressure at sea level and variations in density, pressure and temperature
- explain the purpose and use of the ISA and the use of equations for determining pressure, density and temperature.

Individual learner activities:

- investigation and report on the constitution and behaviour of the atmosphere
- use of relevant equations for pressure, density and temperature.

Prepare for and carry out **Assignment 1: Constitution and Behaviour of the Atmosphere** (P1, P2, M1)

Topic and suggested assignments/activities and/assessment

Whole-class teaching:

- explain the principles of lift, drag, thrust and weight
- explain boundary layers and distribution of pressure around an aerofoil
- explain Bernoulli's principle, the use of Bernoulli's equation and Newton's laws of motion
- describe a main rotor blade using technical terms
- explain the principles of lift generation
- tutor demonstration using smoke tunnel and wind-tunnel or wind generator plus aerofoil sections to identify and understand the nature of airflow and lift and drag over an aerofoil section

Individual learner activities:

- investigation of aerodynamic principles and the generation of lift.

Practical workshop activities:

- investigation of a main rotor blade
- carry out practical activities using available smoke tunnel and wind tunnel apparatus and record and comment on observations.

Prepare for and carry out **Assignment 2: Aerodynamic Principles and Lift Generation** (P3, P4, P5, M2)

Whole-class teaching:

- explain the principles of helicopter flight
- describe the purpose and methods used to obtain control of a helicopter during flight.

Individual learner activities:

- case study and investigation into helicopter flight and methods of control.

Prepare for and carry out **Assignment 3: Helicopter Flight and Control** (P6, P7, P8, M3)

Whole-class teaching:

- explain the different frequency vibration orders and the effects of rotor and transmission vibration
- explain vibration analysis, vibration planes and monitoring equipment
- explain main rotor balancing and tracking techniques
- tutor demonstration of use of tracking and balancing equipment and vibration analysis equipment.

Practical workshop activities:

- investigation and use of main and tail rotor tracking and balancing equipment and techniques.

Prepare for and carry out **Assignment 4: Helicopter Vibration and Rotor Tracking and Balancing Techniques** (P9, P10, M4, D1, D2)

Feedback on assessment and unit evaluation

Assessment

Evidence of outcomes can be collected from assignments and practical activities carried out in either a laboratory or in the workplace. The pass grade specifies the minimum acceptable level required by learners and the internal assessments, mainly assignment based, will cover all the learning outcomes, but not necessarily all the topics included in the content. Achievement of a merit or distinction grade will require answers that demonstrate additional depth and/or breadth of treatment.

Learning outcome 1 covers the environment in which the helicopter flies. Learners will need to have a sound knowledge of the changes that occur throughout the atmosphere so that they can appreciate the constraints that limit flight.

Learning outcome 2 is concerned with the generation of aerodynamic lift from an aerofoil section and the accurate description of an aerofoil. Learners should focus on the differing lift and drag forces which are produced at varying angles of attack.

Learning outcome 3 is concerned with the actual flight of the helicopter and the problems associated with rotary wing aircraft flight. Learners must understand the flight modes of the helicopter and be able to recognise and explain the problems associated with flight and the methods employed to overcome these problems. They will also need to understand which of the controls control the different aspects of flight and how they do so.

For learning outcome 4, learners will need to be aware of the three planes of vibration and the orders of vibration produced by the rotating systems. Ideally learners should be given opportunities to carry out vibration monitoring and tracking and balancing test flights themselves. However it is acceptable for them to use the information gained from such flights in order to investigate problems and make recommendations for corrective action.

To achieve a pass, learners should have an understanding of the atmosphere in which flight takes place and the way in which lift is generated by an aerofoil and they will be able to use this information to explain the way in which a helicopter flies. They should understand why vibration levels in a helicopter are high and where the vibrations emanate from. They will also need to understand the main reason for high main rotor vibration levels and how this may be reduced.

To achieve a merit, learners should have an understanding of the behaviour of the air in the lower part of the atmosphere and be able to calculate temperature pressure and density at three different altitudes, within the troposphere, from known data at sea level.

They will understand how lift and drag vary as a helicopter blade varies its angle of attack and how this is used to control flight. They will understand the aerodynamic problems associated with helicopter flight and how these are controlled by design. They will also understand the use of vibration monitoring equipment on a helicopter.

To achieve a distinction, learners should have a comprehensive knowledge of helicopter main rotor tracking and balancing techniques and vibration monitoring. They will be able to recognise out of track blades, out of balance heads and high vibration levels. They will understand the vibration frequencies associated with differing rotating components and be able to recognise out of limits vibrations and deduce corrective actions.

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	Constitution and Behaviour of the Atmosphere	A formal assignment requiring learners to respond to written tasks.	Written responses to set written tasks.
P3, P4, P5, M2	Aerodynamic Principles and Lift Generation	A formal assignment requiring learners to respond to written tasks.	Written responses to set written tasks.
P6, P7, P8, M3	Helicopter Flight and Control	A formal assignment requiring learners to respond to written tasks.	Written responses to set written tasks.
P9, P10, M4, D1, D2	Helicopter Vibration and Rotor Tracking and Balancing Techniques	A two-part activity, requiring learners to first provide a written response to set tasks. A second part requiring learners to analyse and interpret a tracking report and a vibration test.	Responses to set tasks and a written report of recommendations for corrective actions and maintenance.

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
		Theory of Flight
		Helicopter Gas Turbine Engines, Transmissions, Rotors and Structures

Essential resources

It is essential that learners have access to actual helicopter airframes, control systems, main rotor heads and tail rotors. Aircraft publications or manuals, manufacturers' quality control procedures and appropriate test equipment and instruments will also need to be available.

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

Kroes M, Watkins W and Delp F – *Aircraft Maintenance and Repair* (McGraw Hill, 2007) ISBN 0077231546

Wagtendonk W J – *Principles of Helicopter Flight* (Aviation Supplies, 2007) ISBN 1560276495

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 carrying out simple calculations to determine lift and drag on an aerofoil.

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	
Identify the situation or problem and the mathematical methods needed to tackle it	carrying out calculations to determine lift and drag on an aerofoil
English	
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	investigating and researching helicopter flight principles and aerodynamics using aircraft documentation and manuals
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	<ul style="list-style-type: none"> explaining the generation of lift and drag by an aerofoil section with reference to Bernoulli's theorem and Newton's laws describing a main rotor blade in technical terms describing the modes of flight that are possible in a helicopter describing how main rotors are arranged to compensate for gyroscopic precession describing the planes of vibration and the orders of vibration found on a helicopter.