Unit 68: Principles and Applications of Aircraft Physical Science

Unit code: R/600/7189

QCF Level 3: BTEC Nationals

Credit value: 10

Guided learning hours: 60

Aim and purpose

This unit will develop learners' understanding of the structure of matter, light, sound and gyroscopic principles and how these apply to aircraft avionic systems.

Unit introduction

The study of physical science is essential for anyone who wishes to understand the underlying principles of aircraft avionic systems and the way that they function. This unit will develop learners' understanding of the affects that microstructure has on the physical properties of aerospace metallic and non-metallic materials.

The nature of light and geometrical optics is covered, and learners will apply these principles to aircraft optical systems. The unit will also cover longitudinal and transverse waves and these are applied to aircraft sound and radio transmission systems. Finally, the dynamic principles of gyroscopic motion are covered and are applied to the operation and behaviour of aircraft gyroscopic instruments such as the attitude indicator, turn and slip indicator and the turn coordinator.

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 those taking the European Aviation Safety Agency (EASA) Part 66 examination.

Learning outcomes

On completion of this unit a learner should:

1 Understand the microstructure of matter and how chemical bonding affects the properties of aerospace metallic and non-metallic materials

2 Understand the characteristics of light and the laws of optics in relation to mirrors, lenses and aircraft fibre and laser optic systems

3 Be able to apply the characteristics of transverse and longitudinal waves to aircraft sound and radio communication systems

4 Be able to apply the dynamic principles that govern the behaviour of gyroscopes to the operation of aircraft basic gyroscopic instruments.

Unit content

1 Understand the microstructure of matter and how chemical bonding affects the properties of aerospace metallic and non-metallic materials

Structure: atoms (such as nucleus, electrons, electron shells, atomic number, atomic mass); molecules and mixtures; states (solid, liquid and gas), changes between states (observable, latent); continuous heat addition

Chemical bonding and material properties: bonding eg covalent, metallic, electrovalent, van der Waals, elements, relationship to periodic table; materials eg thermosetting, thermoplastics, metals, carbon; properties eg strength, hardness, reworking, remoulding, electrical resistance, electro-magnetic, conductivity, thermal capacity

2 Understand the characteristics of light and the laws and definitions of optics to mirrors, lenses and aircraft fibre and laser optic systems

Characteristics of light: light as electromagnetic energy; light travel (rays, beams, bending); speed of light through different mediums

Laws and definitions of optics: laws (reflection, refraction, Snell's); optical definitions (angle of incidence, angle of reflection, angle of refraction, refractive index), mirrors and lenses (such as focal length, normal, centre of curvature, principle axis, concave, convex)

Mirrors, lenses, fibre and laser optic systems: curved mirrors eg nature and height of image, use of formulae, $\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$, $\frac{h_i}{h_o}=\frac{v}{u}$; convex lenses eg nature of image (inverted, real, virtual), ray diagrams, formula, focal length, centre of curvature; fibre optic light propagation (critical angle, total internal reflection); fibre and laser optic systems eg fibre cable cladding and core, fibre optic components, prisms, ring laser gyroscope

3 Be able to apply the characteristics of transverse and longitudinal waves to aircraft sound and radio communication systems

Transverse and Longitudinal wave characteristics: fundamental characteristics (wave length, amplitude, frequency, velocity, speed of sound, compression, rarefaction); other characteristics eg constructive and destructive interference effects, reflection, refraction, diffraction, speed of sound and radio waves, use of $v = f\lambda$, $SofS \simeq 20\sqrt{T}$

Aircraft sound and radio communication systems: sound eg harmonics (such as pitch, intensity, quality) Doppler affect, flaw detection (such as principles, equipment, method); radio communication methods eg carrier waves, modulation and demodulation, aircraft communication wave bands and frequencies, communication equipment (such as transmitter, receiver, microphone, digitiser)

4 Be able to apply the dynamic principles that govern the behaviour of gyroscopes to the operation of aircraft basic gyroscopic instruments

Dynamic principles: Newton's second and third laws; momentum; inertia and gyroscopic rigidity; application of torque and gyroscopic precession; Sperry's rule of precession

Basic gyroscopic instruments: behaviour eg real wander, apparent wander and transport wander; operation of instruments eg attitude indicator, turn and slip indicator, turn coordinator, heading indicator, review of light and the ring laser gyroscope

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 with the aid of a diagram describe the sub-atomic nature of the atom and state the essential difference between molecules and mixtures	**M1** explain how the position of the elements in the periodic table dictates the bonding method used for their combination and explain why the metallic bond enables metals to be good conductors of electricity and heat	**D1** explain the principles of speech transmission via a radio carrier wave and explain the form and function of the equipment needed to transmit and receive this kind of transmission
P2 define the three states of matter and explain the observable and latent changes that take place with continuous heat addition	**M2** use the formulae $\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$ and $\frac{h_i}{h_o}=\frac{v}{u}$ to determine the nature and height of the image when the object is placed in front of a curved mirror and a convex lens, of known focal length and at a known distance	**D2** compare the operation and merits of a turn and slip indicator with a modern turn coordinator.
P3 explain how covalent and van der Waals bonding give thermosetting and thermoplastic materials their distinct properties including their ability to be reworked or moulded	**M3** solve a problem related to the speed of sound and one related to the speed of electromagnetic waves using the equations $SofS \simeq 20\sqrt{T}$ and $v = f\lambda$	
P4 explain the electromagnetic nature of light, how light travels and the effect on the velocity and direction of light as it passes through different mediums	**M4** explain the principle of operation of a ring laser gyroscope.	

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 state the laws of reflection, refraction and Snell's law and, with the aid of sketches, show the normal, the angles of reflection and refraction and show how the refractive index affects the angle of refraction [IE1, IE6]		
P6 with respect to mirrors and convex lenses define focal length, centre of curvature and principle axis and use ray diagrams to solve two problems involving a plane mirror and a convex lens respectively [IE1, IE6]		
P7 define critical angle and total internal reflection and explain how these phenomena enable light to travel down fibre optic cable and why it is necessary to clad these cables		
P8 define the fundamental characteristics of both transverse and longitudinal waves and explain what is meant by constructive and destructive interference		
P9 with respect to sound and radio communication define pitch, intensity and quality of sound, modulation and demodulation and explain what is meant by the Doppler effect		
P10 explain how Newton's laws and the concept of momentum and inertia determine the rigidity of a rotating gyroscope and explain, using Sperry's rule, the nature of precession when a gyroscope is acted upon by an external torque		

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:**
P11 with respect to a gyroscopic instrument explain the terms apparent wander and real wander and, explain the operation of an attitude indicator.		

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 are probably best delivered in order. When delivering the material on atomic structure and bonding in learning outcome 1, molecular models could be used to demonstrate the way in which atoms combine. Sand and water could also be used to demonstrate a mixture, as opposed to molecular bonding.

A practical demonstration could be used to deliver the subject of change of state and latent heat. This could involve melting ice to produce water, then boiling the water to produce steam. Learners need to be aware of the nature of primary bonds and how these bonds are related to valance and to the periodic table. The nature and strength of secondary bonds should also be emphasised and their strengths compared with those of primary bonds, for example comparing the covalent-covalent bonds in diamond with the covalent-secondary bonds in a thermoplastic. Using a plastic bag to emphasise the directionality and strength of these bonds may also prove useful. Once learners understand the microscopic nature of bonding, they can then relate this bonding to the macroscopic properties of aircraft materials particularly, with respect to strength, hardness, electrical and thermal conductivity and their ability to be magnetised/demagnetised.

When delivering learning outcome 2 an initial introduction should emphasise light as electromagnetic energy and the way in which it travels through free space and various mediums.

The relationship between wavelength, frequency and velocity could be mentioned when studying the electromagnetic spectrum, but calculations using mathematical formula might best be left until the study of transverse and longitudinal waves in learning outcome 3. In this way, most of the delivery time for learning outcome 2 can concentrate on geometric optics, which learners often find difficult. This can especially be the case when dealing with mirrors and lenses, where, particularly for lenses, the nature of the image other than when defined using formulae is often difficult to visualise. A lot of practice in the construction of ray diagrams and the use of formulae, together with possible experiments involving mirrors, lenses and prisms is therefore recommended.

When looking at and using the laws of reflection and refraction, the concept of the critical angle and total internal reflection should be emphasised. This will enable learners to understand the application of these laws to light propagation in fibre optic cables and the reflection of light in prisms and ring laser gyroscopes.

In delivering learning outcome 3, the differences and characteristics of both longitudinal waves and electromagnetic transverse waves should be emphasised. This should include the speed of sound for longitudinal waves and their dependence on the density and temperature of the medium through which they pass. The use of a long length of rope and a slinky spring would be particularly appropriate aids for an understanding of wave energy and motion.

Although learners will need to fully understand the way in which electromagnetic radio waves are used as a carrier wave for sound, this should not include any involvement with wave mathematics, other than the simple relation $v = f\lambda$. The ideas associated with the Doppler effect should also be fully understood.

Pictorial representations of the equipment necessary for transmission of sound and radio communication between earth and aircraft, aircraft to aircraft and the use of satellites should be taught and the frequency bands for the more common aircraft communication systems should also be known.

When delivering learning outcome 4 the concept of momentum and inertia should be highlighted. Their relationship to gyroscopic rigidity and precession will need to be emphasised, as will the use of Sperry's rule. The classic bicycle wheel or similar should be used to aid understanding of gyroscopic precession. When applying gyroscopic principles to aircraft instruments, cut away models of these instruments would prove particularly useful in aiding learners' understanding.

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 sub-atomic nature of matter, the states of matter and how to define them and look at the changes (observable, latent) that take place between states with continuous heat addition (perhaps using ice, water and steam as examples). *Small-group activity:* • observe/carryout experiments in a physics laboratory on latent heat and present a written report on findings. Whole-class teaching: • explain the nature of chemical bonding (covalent, metallic and electrovalent) and their relationship to the periodic table and electron valance, secondary van der Waals bonding • explain the relationship between chemical bonding and material properties; metallic bonding and relationship to electro-magnetism, electrical and thermal conductivity; primary/secondary bonding and relationship to thermosetting and thermoplastic materials. *Individual learner activity*: • multiple choice quiz on bonding and material properties.
Prepare for and carry out **Assignment 1: Microstructure, Chemical Bonding and Material Properties** (P1, P2, P3 M1).
Whole-class teaching: • explain the phenomenon of light, travelling as rays, beams, bending and speed of light through different mediums • describe the laws and effects of refraction, reflection, Snell's law. *Individual learner activities*: • tasks involving problems on light and its reflection and refraction through different mediums. *Whole-class teaching:* • discuss the optical definitions (such as focal length, normal, centre of curvature, principle axis, concave, convex), ray diagrams and the use of formulae to determine nature of image in plain and curved mirrors and through convex lenses. *Individual learner activities*: • tasks involving problems on optics, using ray-diagrams, definitions and formulae. *Whole-class teaching:* • describe the make-up and explain the principles of operation of fibre optic cable and components, prisms and make brief mention of the ring laser gyroscope, as an optic system (covered in detail in learning outcome 4). *Individual learner activity*: • multiple-choice quiz on light, optics and optical systems.
Prepare for and carry out **Assignment 2: Light, Optics and Aircraft Optic Systems** (P4, P5, P6, P7, M2).

Topic and suggested assignments/activities and/assessment
Whole-class teaching: • using suitable laboratory equipment, explain the nature of transverse and longitudinal waves, their use as energy carriers, characteristics, sound waves, electromagnetic waves, constructive and destructive interference, speed of sound, velocity, frequency and wave length. *Individual learner or small group activities:* • observe/participate in experiments (eg longitudinal waves, using slinky spring, wave fronts using pebble in a tank, transverse waves using cork on water, water waves diffracting through narrow opening in water tank, light waves and use of diffraction grating, tuning fork and sound waves) and write-up comments and findings. *Whole-class teaching:* • using appropriate equipment where possible, explain harmonics, Doppler effect and ultrasonic flaw detection (if appropriate) • explain carrier waves, modulation, demodulation and appropriate aircraft communication systems, aircraft communication wave bands and equipment. *Individual learner activity*: • multi-choice quiz on waves, sound and radio communications.
Prepare for and carry out **Assignment 3: Waves, Sound and Aircraft Communication Systems** (P8, P9, M3, D1).
Whole-class teaching: • using a gyroscopic model (bicycle wheel and axle and/or real gyroscope), explain Newton's laws, momentum and inertia and their application to gyroscopic movement, rigidity, precession and use of Sperry's rule • demonstrate gyroscope rigidity and precession, with applied torque, direction of precession. *Individual learner activities*: • tutor-led problem solving exercises on gyroscopic principles. *Whole-class teaching:* • using appropriate basic gyroscopic instruments, explain behaviour (wander, apparent wander, transport wander), construction and operation (such as attitude indicator, turn and slip indicator, turn coordinator and review of light and operation of the ring laser gyroscope). *Individual learner activity* • multiple-choice quiz on gyroscopic principles and aircraft instruments.
Prepare for and carry out **Assignment 4: Gyroscopic Principles and Instruments** (P10, P11, M4, D2).
Feedback on assessment and unit evaluation.

Assessment

A total of four assignments could be used to assess this unit. It is expected that a range of assessment methods will be used for this unit. Evidence may be gathered from written responses to formal timed assignments and investigative assignments. Wherever possible assessment evidence should be gathered from reports, resulting from learner-led practical work.

The first assignment could involve a series of written tasks requiring learners to describe the sub-atomic nature of the atom and state the essential differences between molecules and mixtures (P1). They must be able to define the three states of matter (at the microscopic level including an explanation of atomic proximity, movements and binding forces, that differ for each state) and explain the observable and latent changes that take place with continuous heat addition (P2). They must explain how secondary van der Waals bonds give thermoplastic materials their distinct properties (P3). The assignment should also require learners to explain how the position of the elements in the period table, dictates the type of bond that is likely to form between them and discuss in detail the nature of the metallic bond and explain why this bond enables metals to be good conductors of electricity and heat (M1).

A second assignment, covering learning outcome 2 is also likely to be a series of formal written tasks. These will need to give learners an opportunity to explain the electro-magnetic nature of light and how it travels, including the changes that take place to the light beam as it passes through different mediums (P4). Learners will need to define the laws of reflection, refraction and Snell's law and be able to sketch the normal, the angles of reflection and refraction and show how the refractive index affects the angle of refraction (P5). They need to be able to define the basic optical parameters and be able to use ray diagrams to solve two problems, involving a mirror and a lens, respectively (P6). These optical problems will require the learner to find one of the optical parameters and/or the nature of the image. Learners need to be able to define critical angle and total internal reflection and use these definitions to explain how light is able to travel down a fibre optic cable and why it is necessary to clad these cables (P7). Learners will also need to use the standard light formulae to determine, the nature and height of images placed in front of a curved mirror and convex lens (M2).

For learning outcome 3, the assignment used will need to give learners an opportunity to describe the characteristics of transverse and longitudinal waves and explain the nature of constructive and destructive interference (P8). They will need to define the parameters (pitch, intensity, sound quality, modulation, demodulation) and explain the Doppler affect (P9). Further tasks allowing achievement of the related merit and distinction criteria can be built into this assignment. These should enable learners to solve problems relating to the speed of sound and speed of electromagnetic waves (M3) and explain the principles of speech transmission via a radio carrier wave and explain the form and function of the equipment needed to transmit and receive this kind of transmission (D1). The explanation should include all equipment needed to transmit/receive from voice to voice.

The fourth assignment could include a series of written tasks requiring learners to explain how Newton's laws, momentum and inertia are used to determine the rigidity of a rotating gyroscope and to use Sperry's rule to determine the nature of the precession when, the gyroscope has been acted upon by an external torque (P10). Learners must also be able to explain the concepts, apparent wander and real wander and be able to explain the operation of an aircraft attitude indicator (P11). Learners must be able to explain in detail the principles of operation of a ring laser gyroscope (M4) and compare the operation of a turn and slip indicator with a modern turn coordinate (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	Microstructure, Chemical Bonding and Material Properties	A formal assignment requiring learners to respond to written tasks.	Written response to set tasks, carried out under controlled conditions.
P4, P5, P6, P7, M2	Light, Optics and Aircraft Optic Systems	A formal assignment requiring learners to respond to written tasks.	Written response to set tasks, carried out under controlled conditions.
P8, P9, M3, D1	Waves, Sound and Aircraft Communication Systems	Two part assignment consisting of a formal written part requiring learner to respond to written questions (P8, P9, M3) and an investigative assignment (D1).	Written response to set tasks, carried out under controlled conditions (P8, P9, M3) and a written report resulting from investigation (D1).
P10, P11, M4, D2	Gyroscopic Principles and Instruments	Two part assignment consisting of a formal written part requiring learner to respond to written questions (P10, P11,) and an investigative assignment (M4, D2).	Written response to set tasks, carried out under controlled conditions (P10, P11) 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 Mechanical Science
		Theory of Flight

This unit has been mapped against the EASA Part-66 examinations and when taken with *Unit 66: Theory of Flight* and *Unit 67: Principles and Applications of Aircraft Mechanical Science*, covers the knowledge requirements for Module 2 Physics.

Essential resources

As a minimum, learners will require sight of suitable learning aids and equipment that should include but not be limited to:

- latent heat and change of state demonstration equipment
- slinky springs, water tank equipment to demonstrate nature of longitudinal and transverse waves
- pitching fork, or other means of demonstrating the pitch/frequency of sound
- gyroscopic models (such as a bicycle wheel and axle, gyroscopic rotor) to demonstrate gyroscopic motion.
- examples of fibre optic cables and connectors and basic gyroscopic instruments
- access to aircraft radio communications equipment and an ultra sound non-destructive test set would be of benefit, but is not essential.

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* (Elsevier, 2004) ISBN 075065015X

Tooley M and Wyatt D – *Aircraft Communication and Navigation Systems*: *Principles, Operation and Maintenance* (Elsevier, 2007) ISBN

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 solving problems relating to aircraft physical science supporting conclusions using reasoned arguments and evidence.

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 ...
Independent enquirers	analysing and evaluating information, judging its relevance and value
Reflective learners	setting goals with success criteria for their development and work.

Functional Skills – Level 2

Skill	When learners are ...
Mathematics	
Select and apply a range of skills to find solutions	using the laws of optics and relevant formulae to solve problems relating to optics, mirrors and lenses applying the characteristics of transverse and longitudinal waves to aircraft sound and communication systems applying dynamic principles that govern the behaviour of gyroscopes to aircraft instruments
Draw conclusions and provide mathematical justifications	solving a range of problems relating to optics, mirrors and lenses
English	
Speaking and listening – make a range of contributions to discussions and make effective presentations in a wide range of contexts	explaining the microstructure of matter and how chemical bonding affects the properties of aerospace materials explaining the characteristics of light and laws of optics defining characteristics of transverse and longitudinal waves explaining the principles of sound and radio communication explaining the principles that govern the behaviour of gyroscopes
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	researching and investigating the principles and applications of aircraft physical science
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	explaining the microstructure of matter and how chemical bonding affects the properties of aerospace materials explaining the characteristics of light and laws of optics defining characteristics of transverse and longitudinal waves explaining the principles of sound and radio communication explaining the principles that govern the behaviour of gyroscopes.