Syllabus
(Aerospace Engineering)

Year 1 & Year 2

Kings Cornerstone International College

Unit 1: Engineering Design

Unit code K/615/1475

Unit type Core

Unit level 4

Credit value 15

Introduction

The tremendous possibilities of the techniques and processes developed by engineers can only be realised by great design. Design turns an idea into a useful artefact, the problem into a solution, or something ugly and inefficient into an elegant, desirable and cost effective everyday object. Without a sound understanding of the design process the engineer works in isolation without the links between theory and the needs of the end user.

The aim of this unit is to introduce students to the methodical steps that engineers use in creating functional products and processes; from a design brief to the work, and the stages involved in identifying and justifying a solution to a given engineering need.

Among the topics included in this unit are: Gantt charts and critical path analysis, stakeholder requirements, market analysis, design process management, modelling and prototyping, manufacturability, reliability life cycle, safety and risk, management, calculations, drawings and concepts and ergonomics.

On successful completion of this unit students will be able to prepare an engineering design specification that satisfies stakeholders' requirements, implement best practice when analysing and evaluating possible design solutions, prepare a written technical design report, and present their finalised design to a customer or audience.

Learning Outcomes

By the end of this unit students will be able to:

1. Plan a design solution and prepare an engineering design specification in response to a stakeholder's design brief and requirements.
2. Formulate possible technical solutions to address the student-prepared design specification.
3. Prepare an industry-standard engineering technical design report.
4. Present to an audience a design solution based on the design report and evaluate the solution/presentation.

Essential Content

LO1 Plan a design solution and prepare an engineering design specification in response to a stakeholder's design brief and requirements

Planning techniques used to prepare a design specification:

Definition of client's/users objectives, needs and constraints

Definition of design constraints, function, specification, milestones

Planning the design task: Flow charts, Gantt charts, network and critical path analysis necessary in the design process

Use of relevant technical/engineering/industry standards within the design process

Design process:

Process development, steps to consider from start to finish

The cycle from design to manufacture

Three- and five-stage design process

Vocabulary used in engineering design

Stage of the design process which includes:

Analysing the situation, problem statement, define tasks and outputs, create the design concept, research the problem and write a specification

Suggest possible solutions, select a preferred solution, prepare working drawings, construct a prototype, test and evaluate the design against objectives, design communication (write a report)

Customer/stakeholder requirements:

Converting customer request to a list of objectives and constraints

Interpretation of design requirements

Market analysis of existing products and competitors

Aspects of innovation and performance management in decision-making

LO2 Formulate possible technical solutions to address the student-prepared design specification

Conceptual design and evaluating possible solutions:

Modelling, prototyping and simulation using industry standard software, (e.g. AutoCAD, Catia, SolidWorks, Creo) on high specification computers

Use of evaluation and analytical tools, e.g. cause and effect diagrams, CAD, knowledge-based engineering

LO3 Prepare an industry-standard engineering technical design report

Managing the design process:

Recognising limitations including cost, physical processes, availability of material/components and skills, timing and scheduling

Working to specifications and standards, including:

The role of compliance checking, feasibility assessment and commercial viability of product design through testing and validation

Design for testing, including:

Material selection to suit selected processes and technologies

Consideration of manufacturability, reliability, life cycle and environmental issues

The importance of safety, risk management and ergonomics

Conceptual design and effective tools:

Technologies and manufacturing processes used in order to transfer engineering designs into finished products

LO4 Present to an audience a design solution based on the design report and evaluate the solution/presentation

Communication and post-presentation review:

Selection of presentation tools

Analysis of presentation feedback

Strategies for improvement based on feedback

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Plan a design solution and prepare an engineering design specification in response to a stakeholder’s design brief and requirements</td><td rowspan="2">D1 Compare and contrast the completed design specification against the relevant industry standard specification</td></tr>
<tr><td>P1 Produce a design specification from a given design brief

P2 Explain the influence of the stakeholder’s design brief and requirements in the preparation of the design specification

P3 Produce a design project schedule with a graphical illustration of the planned activities</td><td>M1 Evaluate potential planning techniques, presenting a case for the method chosen

M2 Demonstrate critical path analysis techniques in design project scheduling/planning and explain its use</td></tr>
<tr><td colspan="2">LO2 Formulate possible technical solutions to address the student-prepared design specification</td><td rowspan="2">D2 Evaluate potential technical solutions, presenting a case for the final choice of solution</td></tr>
<tr><td>P4 Explore industry standard evaluation and analytical tools in formulating possible technical solutions

P5 Use appropriate design techniques to produce a possible design solution</td><td>M3 Apply the principles of modelling, simulation and/or prototyping, using appropriate software, to develop an appropriate design solution</td></tr>
</table>

Pass	Merit	Distinction
LO3 Prepare an industry-standard engineering technical design report		**D3** Evaluate the effectiveness of the industry standard engineering technical design report for producing a fully compliant finished product
P6 Prepare an industry-standard engineering technical design report **P7** Explain the role of design specifications and standards in the technical design report	**M4** Assess any compliance, safety and risk management issues specific to the technical design report	
LO4 Present to an audience a design solution based on the design report and evaluate the solution/presentation		**D4** Justify potential improvements to the design solution and/or presentation based on reflection and/or feedback
P8 Present the recommended design solution to the identified audience **P9** Explain possible communication strategies and presentation methods that could be used to inform the stakeholders of the recommended solution	**M5** Reflect on the effectiveness of the chosen communication strategy in presenting the design solution	

Recommended Resources

Textbooks

DUL, J. and WEERDMEESTER, B. (2008) *Ergonomics for beginners*. 3rd Ed.Boca Raton: CRC Press.

DYM, C.L., LITTLE, P. and ORWIN, E. (2014) *Engineering Design: a Project BasedIntroduction*. 4th Ed. Wiley.

GRIFFITHS, B. (2003) *Engineering Drawing for Manufacture*.Kogan Page Science.

REDDY, K.V. (2008) *Textbook of Engineering Drawing*. 2nd Ed. Hyderabad:BS Publications.

Websites

www.epsrc.ac.uk	Engineering and Physical Sciences Research Council (General Reference)
www.imeche.org	Institution of Mechanical Engineers (General Reference)

Unit 2: Engineering Maths

Unit code	**M/615/1476**
Unit type	**Core**
Unit level	**4**
Credit value	**15**

Introduction

The mathematics that is delivered in this unit is that which is directly applicable to the engineering industry, and it will help to increase students' knowledge of the broad underlying principles within this discipline.

The aim of this unit is to develop students' skills in the mathematical principles and theories that underpin the engineering curriculum. Students will be introduced to mathematical methods and statistical techniques in order to analyse and solve problems within an engineering context.

On successful completion of this unit students will be able to employ mathematical methods within a variety of contextualised examples, interpret data using statistical techniques, and use analytical and computational methods to evaluate and solve engineering problems.

Learning Outcomes

By the end of this unit students will be able to:

1. Identify the relevance of mathematical methods to a variety of conceptualised engineering examples.
2. Investigate applications of statistical techniques to interpret, organise and present data.
3. Use analytical and computational methods for solving problems by relating sinusoidal wave and vector functions to their respective engineering applications.
4. Examine how differential and integral calculus can be used to solve engineering problems.

Essential Content

LO1 **Identify the relevance of mathematical methods to a variety of conceptualised engineering examples**

Mathematical concepts:

Dimensional analysis

Arithmetic and geometric progressions

Functions:

Exponential, logarithmic, trigonometric and hyperbolic functions

LO2 **Investigate applications of statistical techniques to interpret, organise and present data**

Summary of data:

Mean and standard deviation of grouped data

Pearson's correlation coefficient

Linear regression

Charts, graphs and tables to present data

Probability theory:

Binomial and normal distribution

LO3 **Use analytical and computational methods for solving problems by relating sinusoidal wave and vector functions to their respective engineering application.**

Sinusoidal waves:

Sine waves and their applications

Trigonometric and hyperbolic identities

Vector functions:

Vector notation and properties

Representing quantities in vector form

Vectors in three dimensions

LO4 **Examine how differential and integral calculus can be used to solve engineering problems**

Differential calculus:

Definitions and concepts

Definition of a function and of a derivative, graphical representation of a function, notation of derivatives, limits and continuity, derivatives; rates of change, increasing and decreasing functions and turning points

Differentiation of functions

Differentiation of functions including:

- standard functions/results
- using the chain, product and quotient rules
- second order and higher derivatives

Types of function: polynomial, logarithmic, exponential and trigonometric (sine, cosine and tangent), inverse trigonometric and hyperbolic functions

Integral calculus:

Definite and indefinite integration

Integrating to determine area

Integration of functions including:

- common/standard functions
- using substitution
- by parts

Exponential growth and decay

Types of function: algebraic including partial fractions and trigonometric (sine, cosine and tangent) functions

Engineering problems involving calculus:

Including: stress and strain, torsion, motion, dynamic systems, oscillating systems, force systems, heat energy and thermodynamic systems, fluid flow, AC theory, electrical signals, information systems, transmission systems, electrical machines, electronics

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Identify the relevance of mathematical methods to a variety of conceptualised engineering examples		**LO1 & LO2** **D1** Present data in a method that can be understood by a non-technical audience
P1 Apply dimensional analysis techniques to solve complex problems **P2** Generate answers from contextualised arithmetic and geometric progressions **P3** Determine solutions of equations using exponential, logarithmic, trigonometric and hyperbolic functions	**M1** Use dimensional analysis to derive equations	
LO2 Investigate applications of statistical techniques to interpret, organise and present data		
P4 Summarise data by calculating mean and standard deviation **P5** Calculate probabilities within both binomially distributed and normally distributed random variables	**M2** Interpret the results of a statistical hypothesis test conducted from a given scenario	

Pass	Merit	Distinction
LO3 Use analytical and computational methods for solving problems by relating sinusoidal wave and vector functions to their respective engineering application		**D2** Model the combination of sine waves graphically and analyse the variation in results between graphical and analytical methods
P6 Solve engineering problems relating to sinusoidal functions **P7** Represent engineering quantities in vector form, and use appropriate methodology to determine engineering parameters	**M3** Use compound angle identities to combine individual sine waves into a single wave	
LO4 Examine how differential and integral calculus can be used to solve engineering problems		**D3** Analyse maxima and minima of increasing and decreasing functions using higher order derivatives
P8 Determine rates of change for algebraic, logarithmic and trigonometric functions **P9** Use integral calculus to solve practical problems relating to engineering	**M4** Formulate predictions of exponential growth and decay models using integration methods	

Recommended Resources

Textbooks

SINGH, K. (2011) *Engineering Mathematics Through Applications*. 2nd Ed. Basingstoke:Palgrave Macmillan.

STROUD, K.A. and BOOTH, D.J. (2013) *Engineering Mathematics*. 7th Ed. Basingstoke:Palgrave Macmillan.

Websites

http://www.mathcentre.ac.uk/	Maths Centre (Tutorials)
http://www.mathtutor.ac.uk/	Maths Tutor (Tutorials)

Unit 3: Engineering Science

Unit code	**T/615/1477**
Unit type	**Core**
Unit level	**4**
Credit value	**15**

Introduction

Engineering is a discipline that uses scientific theory to design, develop or maintain structures, machines, systems, and processes. Engineers are therefore required to have a broad knowledge of the science that is applicable to the industry around them.

This unit introduces students to the fundamental laws and applications of the physical sciences within engineering and how to apply this knowledge to find solutions to a variety of engineering problems.

Among the topics included in this unit are: international system of units, interpreting data, static and dynamic forces, fluid mechanics and thermodynamics, material properties and failure, and A.C./D.C. circuit theories.

On successful completion of this unit students will be able to interpret and present qualitative and quantitative data using computer software, calculate unknown parameters within mechanical systems, explain a variety of material properties and use electromagnetic theory in an applied context.

Learning Outcomes

By the end of this unit students will be able to:

1. Examine scientific data using both quantitative and qualitative methods.
2. Determine parameters within mechanical engineering systems.
3. Explore the characteristics and properties of engineering materials.
4. Analyse applications of A.C./D.C. circuit theorems, electromagnetic principles and properties.

Essential Content

LO1 **Examine scientific data using both quantitative and qualitative methods**

International system of units:

The basic dimensions in the physical world and the corresponding SI base units

SI derived units with special names and symbols

SI prefixes and their representation with engineering notation

Interpreting data:

Investigation using the scientific method to gather appropriate data

Test procedures for physical (destructive and non-destructive) tests and statistical tests that might be used in gathering information

Summarising quantitative and qualitative data with appropriate graphical representations

Using presentation software to present data to an audience

LO2 **Determine parameters within mechanical engineering systems**

Static and dynamic forces:

Representing loaded components with space and free body diagrams

Calculating support reactions of beams subjected to concentrated and distributed loads

Newton's laws of motion, D'Alembert's principle and the principle of conservation of energy

Fluid mechanics and thermodynamics:

Archimedes' principle and hydrostatics

Continuity of volume and mass flow for an incompressible fluid

Effects of sensible/latent heat of fluid

Heat transfer due to temperature change and the thermodynamic process equations

LO3 **Explore the characteristics and properties of engineering materials**

Material properties:

Atomic structure of materials and the structure of metals, polymers and composites

Mechanical and electromagnetic properties of materials

Material failure:

Destructive and non-destructive testing of materials

The effects of gradual and impact loading on a material.

Degradation of materials and hysteresis

LO4 **Analyse applications of A.C./D.C. circuit theorems, electromagnetic principles and properties**

D.C. circuit theory:

Voltage, current and resistance in D.C. networks

Exploring circuit theorems (Thevenin, Norton, Superposition), Ohm's law and Kirchhoff's voltage and current laws

A.C. circuit theory:

Waveform characteristics in a single-phase A.C. circuit

RLC circuits

Magnetism:

Characteristics of magnetic fields and electromagnetic force

The principles and applications of electromagnetic induction

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Examine scientific data using both quantitative and qualitative methods		**D1** Analyse scientific data using both quantitative and qualitative methods
P1 Describe SI units and prefix notation **P2** Examine quantitative and qualitative data with appropriate graphical representations	**M1** Explain how the application of scientific method impacts upon different test procedures	
LO2 Determine parameters within mechanical engineering systems		**D2** Compare how changes in the thermal efficiency of a given system can affect its performance.
P3 Determine the support reactions of a beam carrying a combination of a concentrated load and a uniformly distributed load **P4** Use Archimedes' principle in contextual engineering applications **P5** Determine the effects of heat transfer on the dimensions of given materials	**M2** Determine unknown forces by applying d'Alembert's principle to a free body diagram	

Pass	Merit	Distinction
LO3 Explore the characteristics and properties of engineering materials		**D3** Compare and contrast theoretical material properties of metals and non-metals with practical test data
P6 Describe the structural properties of metals and non-metals with reference to their material properties **P7** Explain the types of degradation found in metals and non-metals	**M3** Review elastic and electromagnetic hysteresis in different materials	
LO4 Analyse applications of A.C./D.C. circuit theorems, electromagnetic principles and properties		**D4** Evaluate different techniques used to solve problems on a combined series-parallel RLC circuit using A.C. theory.
P8 Calculate currents and voltages in D.C. circuits using circuit theorems **P9** Describe how complex waveforms are produced from combining two or more sinusoidal waveforms. **P10** Solve problems on series RLC circuits with A.C. theory.	**M4** Explain the principles and applications of electromagnetic induction	

Recommended Resources

Textbooks

BIRD, J. (2012) *Science for Engineering*. 4th Ed. London: Routledge. BOLTON, W. (2006) *Engineering Science*. 5th Ed. London: Routledge.

TOOLEY, M. and DINGLE, L. (2012) *Engineering Science: For FoundationDegree and Higher National*. London: Routledge.

Journals

International Journal of Engineering Science.

International Journal of Engineering Science and Innovative Technology.

Websites

https://www.khanacademy.org/	Khan Academy Physics (Tutorials)

Unit 4: Managing a Professional Engineering Project

Unit code	**A/615/1478**
Unit type	**Core**
Unit level	**4**
Credit value	**15**

Introduction

The responsibilities of the engineer go far beyond completing the task in hand. Reflecting on their role in a wider ethical, environmental and sustainability context starts the process of becoming a professional engineer – a vial requirement for career progression.

Engineers seldom work in isolation and most tasks they undertake require a range of expertise, designing, developing, manufacturing, constructing, operating and maintaining the physical infrastructure and content of our world. The bringing together of these skills, expertise and experience is often managed through the creation of a project.

This unit introduces students to the techniques and best practices required to successfully create and manage an engineering project designed to identify a solution to an engineering need. While carrying out this project students will consider the role and function of engineering in our society, the professional duties and responsibilities expected of engineers together with the behaviours that accompany their actions.

Among the topics covered in this unit are: roles, responsibilities and behaviours of a professional engineer, planning a project, project management stages, devising solutions, theories and calculations, management using a Gantt chart, evaluation techniques, communication skills, and the creation and presentation of a project report.

On successful completion of this unit students will be able to conceive, plan, develop and execute a successful engineering project, and produce and present a project report outlining and reflecting on the outcomes of each of the project processes and stages. As a result, they will develop skills such as critical thinking, analysis, reasoning, interpretation, decision-making, information literacy, and information and communication technology, and skills in professional and confident self-presentation.

This unit is assessed by a Pearson-set theme. The project brief will be set by the centre, based on a theme provided by Pearson (this will change annually). The theme and chosen project within the theme will enable students to explore and examine a relevant and current topical aspect of professional engineering.

***Please refer to the accompanying Pearson-set Assignment Guide and the Theme Release document for further support and guidance on the delivery of the Pearson-set unit.**

Learning Outcomes

By the end of this unit students will be able to:

1. Formulate and plan a project that will provide a solution to an identified engineering problem.
2. Conduct planned project activities to generate outcomes which provide a solution to the identified engineering problem.
3. Produce a project report analysing the outcomes of each of the project processes and stages.
4. Present the project report drawing conclusions on the outcomes of the project.

Essential Content

LO1 **Formulate and plan a project that will provide a solution to an identified engineering problem**

Examples of realistic engineering based problems:

Crucial considerations for the project

How to identify the nature of the problem through vigorous research

Feasibility study to identify constraints and produce an outline specification

Develop an outline project brief and design specification:

Knowledge theories, calculations and other relevant information that can support the development of a potential solution

Ethical frameworks:

The Engineering Council and Royal Academy of Engineering's Statement of Ethical Principles

The National Society for Professional Engineers' Code of Ethics

Regulatory bodies:

Global, European and national influences on engineering and the role of the engineer, in particular: The Royal Academy of Engineering and the UK Engineering Council

The role and responsibilities of the UK Engineering Council and the Professional Engineering Institutions (PEIs)

The content of the UK Standard for Professional Engineering Competence (UKSPEC)

Chartered Engineer, Incorporated Engineer and Engineering Technician

International regulatory regimes and agreements associated with professional engineering:

European Federation of International Engineering Institutions.

European Engineer (Eur Eng)

European Network for Accreditation of Engineering Education

European Society for Engineering Education

Washington Accord

Dublin Accord

Sydney Accord

International Engineers Alliance

Asia Pacific Economic Cooperation (APEC) Engineers Agreement

LO2 **Conduct planned project activities to generate outcomes which provide a solution to the identified engineering problem**

Project execution phase:

Continually monitoring development against the agreed project plan and adapt the project plan where appropriate

Work plan and time management, using Gantt chart or similar.

Tracking costs and timescales

Maintaining a project diary to monitor progress against milestones and timescales

Engineering professional behaviour sources:

Professional responsibility for health and safety (UK-SPEC)

Professional standards of behaviour (UK-SPEC)

Ethical frameworks:

The Engineering Council and Royal Academy of Engineering's Statement of Ethical Principles

The National Society for Professional Engineers' Code of Ethics

LO3 Produce a project report analysing the outcomes of each of the project processes and stages

Convincing arguments:

All findings/outcomes should be convincing and presented logically where the assumption is that the audience has little or no knowledge of the project process

Critical analysis and evaluation techniques:

Most appropriate evaluation techniques to achieve a potential solution

Secondary and primary data should be critiqued and considered with an objective mindset

Objectivity results in more robust evaluations where an analysis justifies a judgement

LO4 Present the project report drawing conclusions on the outcomes of the project

Presentation considerations:

Media selection, what to include in the presentation and what outcomes to expect from it. Audience expectations and contributions

Presentation specifics. Who to invite: project supervisors, fellow students and employers. Time allocation, structure of presentation

Reflection on project outcomes and audience reactions

Conclusion to report, recommendations for future work, lessons learned, changes to own work patterns

Reflection for learning and practice:

The difference between reflecting on performance and evaluating a project – the former considers the research process, information gathering and data collection, the latter the quality of the research argument and use of evidence

The cycle of reflection:

To include reflection in action and reflection on action

How to use reflection to inform future behaviour, particularly directed towards sustainable performance

The importance of Continuing Professional Development (CPD) in refining on-going professional practice

Reflective writing:

Avoiding generalisation and focusing on personal development and the research journey in a critical and objective way

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Formulate and plan a project that will provide a solution to an identified engineering problem		**D1** Illustrate the effect of legislation and ethics in developing the project plan
P1 Select an appropriate engineering based project, giving reasons for the selection **P2** Create a project plan for the engineering project	**M1** Undertake a feasibility study to justify project selection	
LO2 Conduct planned project activities to generate outcomes which provide a solution to the identified engineering problem		**D2** Critically evaluate the success of the project plan making recommendations for improvements
P3 Conduct project activities, recording progress against original project plan	**M2** Explore alternative methods to monitor and meet project milestones, justify selection of chosen method(s)	
LO3 Produce a project report analysing the outcomes of each of the project processes and stages		**LO3 & LO4** **D3** Critically analyse the project outcomes making recommendations for further development
P4 Produce a project report covering each stage of the project and analysing project outcomes	**M3** Use appropriate critical analysis and evaluation techniques to analyse project findings	
LO4 Present the project report drawing conclusions on the outcomes of the project		
P5 Present the project report using appropriate media to an audience	**M4** Analyse own behaviours and performance during the project and suggest areas for improvement	

Recommended Resources

Textbooks

PUGH, P. S. (1990) *Total Design: Integrated Methods for Successful Product Engineering*. Prentice Hall.

STRIEBIG, B., OGUNDIPE, A. and PAPADAKIS, M. (2015) *Engineering Applications inSustainable Design and Development*. Cengage Learning.

ULRICH, K. and EPPINGER, S. (2011) *Product Design and Development*.5th Ed. McGraw-Hill Higher Education.

Journals

Journal of Engineering Design.

Unit 13: Fundamentals of Thermodynamics and Heat Engines

Unit code D/615/1487

Unit level 4

Credit value 15

Introduction

Thermodynamics is one of the most common applications of science in our lives, and it is so much a part of our daily life that it is often taken for granted. For example, when driving your car you know that the fuel you put into the tank is converted into energy to propel the vehicle, and the heat produced by burning gas when cooking will produce steam which can lift the lid of the pan. These are examples of thermodynamics, which is the study of the dynamics and behaviour of energy and its manifestations.

This unit introduces students to the principles and concepts of thermodynamics and its application in modern engineering.

On successful completion of this unit students will be able to investigate fundamental thermodynamic systems and their properties, apply the steady flow energy equation to plant equipment, examine the principles of heat transfer to industrial applications, and determine the performance of internal combustion engines.

Learning Outcomes

By the end of this unit students will be able to:

1. Investigate fundamental thermodynamic systems and their properties.
2. Apply the Steady Flow Energy Equation to plant equipment.
3. Examine the principles of heat transfer to industrial applications.
4. Determine the performance of internal combustion engines.

Essential Content

LO1 **Investigate fundamental thermodynamic systems and their properties**

Fundamental systems:

Forms of energy and basic definitions

Definitions of systems (open and closed) and surroundings

First law of thermodynamics

The gas laws: Charles' Law, Boyle's Law, general gas law and the Characteristic Gas Equation

The importance and applications of pressure/volume diagrams and the concept of work done

Polytrophic processes: constant pressure, constant volume, adiabatic and isothermal systems

LO2 **Apply the Steady Flow Energy Equation to plant equipment**

Energy equations:

Conventions used when describing the behaviour of heat and work

The Non-Flow Energy Equation as it applies to closed systems

Assumptions, applications and examples of practical systems

Steady Flow Energy Equation as applied to open systems

Assumptions made about the conditions around, energy transfer and the calculations for specific plant equipment e.g. boilers, super-heaters, turbines, pumps and condensers

LO3 **Examine the principles of heat transfer to industrial applications**

Principles of heat transfer:

Modes of heat transmission, including conduction, convection & radiation

Heat transfer through composite walls and use of U and k values

Application of formulae to different types of heat exchangers, including recuperator and evaporative

Regenerators

Heat losses in thick and thin walled pipes, optimum lagging thickness

LO4 **Determine the performance of internal combustion engines**

Performance:

Application of the second law of thermodynamics to heat engines

Comparison of theoretical and practical heat engine cycles, including Otto, Diesel and Carnot

Explanations of practical applications of heat engine cycles, such as compression ignition (CI) and spark ignition engines, including their relative mechanical and thermodynamic efficiencies

Describe possible efficiency improvements to heat engines

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Investigate fundamental thermodynamic systems and their properties		**D1** Illustrate the importance of expressions for work done in thermodynamic processes by applying first principles
P1 Describe the operation of thermodynamic systems and their properties **P2** Explain the application of the first law of thermodynamics to appropriate systems **P3** Explain the relationships between system constants for a perfect gas	**M1** Calculate the index of compression in polytrophic processes	
LO2 Apply the Steady Flow Energy Equation to plant equipment		**D2** Produce specific Steady Flow Energy Equations based on stated assumptions in plant equipment
P4 Explain system parameters using the Non-Flow Energy Equation **P5** Apply the Steady Flow Energy Equation to plant equipment	**M2** Derive the Steady Flow Energy Equation from first principles	

Pass	Merit	Distinction
LO3 Examine the principles of heat transfer to industrial applications		**D3** Distinguish the differences between parallel and counter flow recuperator heat exchangers
P6 Determine the heat transfer through composite walls **P7** Apply heat transfer formulae to heat exchangers	**M3** Explore heat losses through lagged and unlagged pipes	
LO4 Determine the performance of internal combustion engines		**D4** Evaluate the performance of two stroke and four stroke diesel engines
P8 Describe with the aid of a PV (pressure volume) diagram the operational sequence of four stroke spark ignition and four stroke compression ignition engines. **P9** Explain the mechanical efficiency of two and four stroke engines	**M4** Review the relative efficiency of ideal heat engines operating on the Otto and Diesel cycles	

Recommended Resources

Textbooks

DUNN, D. (2001) *Fundamental Engineering Thermodynamics*. Longman.

EASTOP, T.D. and MCCONKEY, A. (1996) *Applied Thermodynamics for EngineeringTechnologists*. 5th Ed. Prentice Hall.

EASTOP, T.D. and MCCONKEY, A. (1997) *Applied Thermodynamics for EngineeringTechnologists Student Solution Manual*. 5th Ed. Prentice Hall.

RAYNER, J. (2008) *Basic Engineering Thermodynamics*. 5th Ed. Pearson.

ROGERS, G.F.C. and MAYHEW, Y.R. (1994) *Thermodynamic and Transport Properties ofFluids: S. I. Units*. 5th Ed. Wiley-Blackwell.

Unit 39: Further Mathematics

Unit code H/615/1507

Unit level 5

Credit value 15

Introduction

The understanding of more advanced mathematics is important within an engineering curriculum to support and broaden abilities within the applied subjects at the core of all engineering programmes. Students are introduced to additional topics that will be relevant to them as they progress to the next level of their studies, advancing their knowledge of the underpinning mathematics gained in *Unit 2: Engineering Maths*.

The unit will prepare students to analyse and model engineering situations using mathematical techniques. Among the topics included in this unit are: number theory, complex numbers, matrix theory, linear equations, numerical integration, numerical differentiation, and graphical representations of curves for estimation within an engineering context. Finally, students will expand their knowledge of calculus to discover how to model and solve engineering problems using first and second order differential equations.

On successful completion of this unit students will be able to use applications of number theory in practical engineering situations, solve systems of linear equations relevant to engineering applications using matrix methods, approximate solutions of contextualised examples with graphical and numerical methods, and review models of engineering systems using ordinary differential equations.

Learning Outcomes

By the end of this unit students will be able to:

1. Use applications of number theory in practical engineering situations.
2. Solve systems of linear equations relevant to engineering applications using matrix methods.
3. Approximate solutions of contextualised examples with graphical and numerical methods.
4. Review models of engineering systems using ordinary differential equations.

Essential Content

LO1 **Use applications of number theory in practical engineering situations**

Number theory:

Bases of a number (Denary, Binary, Octal, Duodecimal, Hexadecimal) and converting between bases

Types of numbers (Natural, Integer, Rational, Real, Complex)

The modulus, argument and conjugate of complex numbers

Polar and exponential forms of complex numbers

The use of de Moivre's Theorem in engineering

Complex number applications e.g. electric circuit analysis, information and energy control systems

LO2 **Solve systems of linear equations relevant to engineering applications using matrix methods**

Matrix methods:

Introduction to matrices and matrix notation

The process for addition, subtraction and multiplication of matrices

Introducing the determinant of a matrix and calculating the determinant for a 2x2 and 3x3 matrix

Using the inverse of a square matrix to solve linear equations

Gaussian elimination to solve systems of linear equations (up t 3x3)

LO3 **Approximate solutions of contextualised examples with graphical and numerical methods**

Graphical and numerical methods:

Standard curves of common functions, including quadratic, cubic, logarithm and exponential curves

Systematic curve sketching knowing the equation of the curve

Using sketches to approximate solutions of equations

Numerical analysis using the bisection method and the Newton–Raphson method

Numerical integration using the mid-ordinate rule, the trapezium rule and Simpson's rule

LO4 **Review models of engineering systems using ordinary differential equations**

Differential equations:

Formation and solutions of first-order differential equations

Applications of first-order differential equations e.g. RC and RL electric circuits, Newton's laws of cooling, charge and discharge of electrical capacitors and complex stresses and strains

Formation and solutions of second-order differential equations

Applications of second-order differential equations e.g. mass-spring-damper systems, information and energy control systems, heat transfer, automatic control systems and beam theory and RLC circuits

Introduction to Laplace transforms for solving linear ordinary differential equations

Applications involving Laplace transforms such as electric circuit theory, load frequency control, harmonic vibrations of beams, and engine governors

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Use applications of number theory in practical engineering situations		**D1** Test the correctness of a trigonometric identity using de Moivre's Theorem
P1 Apply addition and multiplication methods to numbers that are expressed in different base systems **P2** Solve engineering problems using complex number theory **P3** Perform arithmetic operations using the polar and exponential form of complex numbers	**M1** Solve problems using de Moivre's Theorem	
LO2 Solve systems of linear equations relevant to engineering applications using matrix methods		**D2** Validate solutions for the given engineering linear equations using appropriate computer software
P4 Calculate the determinant of a set of given linear equations using a 3x3 matrix **P5** Solve a system of three linear equations using Gaussian elimination	**M2** Determine the solution to a set of given engineering linear equations using the Inverse Matrix Method for a 3x3 matrix	

Pass	Merit	Distinction
LO3 Approximate solutions of contextualised examples with graphical and numerical methods		**D3** Critically evaluate the use of numerical estimation methods, commenting on their applicability and the accuracy of the methods
P6 Estimate solutions of sketched functions using a graphical estimation method **P7** Calculate the roots of an equation using two different iterative techniques **P8** Determine the numerical integral of engineering functions using two different methods	**M3** Solve engineering problems and formulate mathematical models using graphical and numerical integration	
LO4 Review models of engineering systems using ordinary differential equations		**D4** Critically evaluate first and second-order differential equations when generating the solutions to engineering situations using models of engineering systems
P9 Formulate and solve first order differential equations related to engineering systems **P10** Formulate and solve second order homogeneous and non-homogeneous differential equations related to engineering systems **P11** Calculate solutions to linear ordinary differential equations using Laplace transforms	**M4** Demonstrate how different models of engineering systems using first-order differential equations can be used to solve engineering problems	

Recommended Resources

Textbooks

BIRD, J. (2014) *Higher Engineering Mathematics*. 7th Ed. London: Routledge.

SINGH, K. (2011) *Engineering Mathematics Trough Applications*. Basingstoke,Palgrave Macmillan.

STROUD, K.A. and BOOTH, D.J. (2013) *Engineering Mathematics*. 7th Ed: Basingstoke,Palgrave Macmillan.

Journals

Communications on Pure and Applied Mathematics. Wiley.

Journal of Engineering Mathematics. Springer.

Journal of Mathematical Physics. American Institute of Physics.

Websites

http://www.mathcentre.ac.uk/	Maths Centre (Tutorials)
http://www.mathtutor.ac.uk/	Maths Tutor (Tutorials)

Unit 23: Computer Aided Design and Manufacture (CAD/CAM)

Unit code	**J/615/1497**
Unit level	**4**
Credit value	**15**

Introduction

The capacity to quickly produce finished components from a software model is now essential in the competitive world of manufacturing. Businesses now invest heavily in Computer Aided Design (CAD) software, Computer Aided Manufacture (CAM) softwareand Computer Numerical Control (CNC) machines to facilitate this, thus reducing product lead times. CAD gives design engineers the platform to creatively model components that meet the specific needs of the consumer. When these models are combined with CAM software, manufacturing is made a reality.

This unit introduces students to all the stages of the CAD/CAM process and to the process of modelling components using CAD software specifically suitable for transferring to CAM software. Among the topics included in this unit are: programming methods, component set up, tooling, solid modelling, geometry manipulation, component drawing, importing solid model, manufacturing simulation,data transfer, CNC machine types and inspections.

On successful completion of this unit students will be able to illustrate the key principles of manufacturing using a CAD/CAM system; produce 3D Solid models of acomponent suitable for transfer into a CAM system; use CAM software to generate manufacturing simulations of a component and design a dimensionally accurate component on a CNC machine using a CAD/CAM system.

Learning Outcomes

By the end of this unit students will be able to:

1 Describe the key principles of manufacturing using a CAD/CAM system.

2 Produce 3D Solid models of a component suitable for transfer into a CAM system.

3 Use CAM software to generate manufacturing simulations of a component.

4 Design and produce a dimensionally accurate component on a CNC machineusing a CAD/CAM system.

Essential Content

LO1 Describe the key principles of manufacturing using a CAD/CAM system

Hardware:

CAD workstation, printers, USB flash drives and network cables

Software:

Operating systems, hard disk requirements, processor, CAD software (e.g. SolidWorks, Autodesk Inventor, CATIA, CAM software: e.g. Edgecam, Delcam, GibbsCAM, SolidCAM)

Inputs:

CAD model, material specifications, tooling data, spindle speeds and feed rate data calculations

Outputs:

CAM files, program code and coordinates, manufacturing sequences, tooling requirements, auxiliary data

Programming methods:

CAD/CAM, manual programming, conversational programming

Component set up:

Zero datum setting, tool set up and offsets, axis of movements

Work holding:

Machine vice, chuck, fixtures, clamping, jigs

Tooling:

Milling cutters, lathe tools, drills, specialist tooling, tool holders, tool turrets and carousels

LO2 **Produce 3D Solid models of a component suitable for transfer into a CAM system**

Solid modelling:

Extrude, cut, fillet, chamfer, holes, sweep, revolve, lines, arcs, insert planes,properties of solid models (e.g. mass, centre of gravity, surface area)

Geometry manipulation:

Mirror, rotate, copy, array, offset

Component drawing:

Set up template, orthographic and multi-view drawings, sections, scale, dimensions, drawing attributes (e.g. material, reference points, tolerances, finish)

LO3 **Use CAM software to generate manufacturing simulations of a component**

Import solid model:

Set up, model feature and geometry identification, stock size, material

Manufacturing simulation:

Operations (e.g. roughing and finishing, pockets, slots, profiling, holes, tool andwork change positions, tool sizes and IDs, speeds and feeds, cutter path simulations, program editing)

LO4 **Design and produce a dimensionally accurate component on a CNC machine using a CAD/CAM system**

CNC machine types:

Machining centres, turning centres, MCUs (e.g. Fanuc, Siemens and Heidenhain)

Data transfer:

Structured data between CAD and CAM software (e.g. datum position and model orientation), file types (e.g. SLDPRT, parasolid, STL, IGES, DXF) and transfer to CNC machine (e.g. network, USB, Ethernet)

Inspection:

Manual inspection (e.g. Using Vernier gauges, bore micrometres), automated inspection (e.g. coordinate measuring machine (CMM), stages of inspection throughout manufacturing process)

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Describe the key principles of manufacturing usinga CAD/CAM system		**D1** Critically evaluate using illustrative examples, the impact of different machining conditions and specifications on component manufacturing
P1 Describe the hardware and software elements of a typical CAD/CAM system **P2** Describe, with examples, the inputs and outputs of the CAD/CAM process **P3** Explain the different methods of component set up, work holding and tooling available on CNC machines	**M1** Analyse the suitability of different programming methods of CNC machines	
LO2 Produce 3D Solid models of a component suitablefor transfer into a CAM system		**D2** Critically evaluate the effectiveness of using a CAD/CAM system and solid modelling to manufacture components
P4 Design and produce a CAD solid model of a component to be manufactured on a CNC machine **P5** Design a working drawing of a component containing specific manufacturing detail	**M2** Assess the importanceof using different geometry manipulation methods for efficient model production	

Pass	Merit	Distinction
LO3 Use CAM software to generate manufacturing simulations of a component		**D3** Analyse the effect of applying different manufacturing techniques and modifications to achievean optimised productiontime
P6 Use CAM software to generate a geometrically accurate CAD solid modelof a component	**M3** Using CAM software generate cutter tool path simulations	
LO4 Design and produce a dimensionally accurate component on a CNC machine using a CAD/CAM system		**D4** Critically analyse, giving illustrative examples the different methods of data transferthrough a CAD/CAM system
P7 Detail a part program for a component using CAM software and transferthe part program to a CNCmachine and manufacture a component **P8** Describe the structural elements of a CNC machining centre **P9** Review a component manufactured on a CNC machine to verify its accuracy	**M4** Analyse different methods of component inspection used in manufacturing	

Recommended Resources

Textbooks

KUNWOO LEE, (2000) *Principles of CAD/CAM/CAE*. Pearson.

McMAHAN, C. and BROWNE, J. (1999) *CADCAM: Principles, Practice and Manufacturing Management*. Prentice Hall.

Links

This unit links to the following related unit:

Unit 1: Engineering Design

Unit 24: Aircraft Aerodynamics

Unit code T/615/1527

Unit level 4

Credit value 15

Introduction

The thrill of designing and building heavier than air machines that mimic bird flight, has always been a source of inspiration to early aviation enthusiasts – their ultimate aim was to produce a heavier than air machine that would not only fly but could be controlled, manoeuvred and then landed safely. The aims of those early day enthusiasts are the same as those for latter day aeronautical engineers, where although far more complex, the study of aircraft aerodynamics is the essential sciencethat underpins aircraft flight.

This unit introduces students to the atmosphere in which aircraft fly and the scientific principles that underpin flight theory; the aerodynamic forces that are generated throughout all phases of flight and the effect they have on the aircraft airframe; how astudy of the nature of high speed air flows lead to the necessary design features for aircraft that fly at supersonic velocities and how aircraft are stabilised and controlled during flight.

Topics included in this unit are: the atmosphere, aerodynamic principles, flight forcesand their effect, high speed airflows, design features of high speed aircraft, stability and control.

On successful completion of this unit students will be able to:

- Examine the properties of the atmosphere and aerodynamic principles and applythem to aircraft flight
- Examine the generation, nature and effects of aerodynamic forces during flight
- Examine the nature of high speed airflows and the need for high speed aircraftdesign features
- Investigate the nature and methods used to stabilise and control aircraft.

Learning Outcomes

By the end of this unit students will be able to:

1 Examine standard atmospheric properties and aerodynamic principles affectingflight.

2 Describe the nature and effect of forces that act on aircraft in flight.

3 Demonstrate the nature of high speed airflows and their effect on fixed wingaircraft design.

4 Investigate the nature and methods used to control and stabilise fixed-wingaircraft.

Essential Content

LO1 Examine standard atmospheric properties and aerodynamic principles affecting flight

The standard atmosphere:

The composition of the air and different layers of the real atmosphere

Nature of the International Standard Atmosphere (ISA): need, function, definitions of standard properties

Use tables and hydrostatic temperature lapse rate and state equations to determine the changing parameters (temperature, pressure, density, viscosity) of the air in the ISA, with changing altitude

Aerodynamic principles:

Airflow definitions; laminar, turbulent, compressible and incompressible flows

Nature of low speed airflow over aerofoil sections; aerofoil terminology, viscosity effects, boundary layer, aerodynamic shape, pressure and flow changes with differing angle of attack (AOA) and airspeeds

Determine experimentally and analytically lift ($L=C_L 1/2 \rho V^2 S$) and drag ($D=C_D 1/2 \rho V^2 S$) forces over aerofoil sections subject to low speed airflows and how lift and drag forces interact over aircraft wings and the significance of the lift/drag ratio as a measure of performance

Define and use the continuity, energy, Bernoulli, isentropic and Reynolds number fluid flow equations to determine low speed airflow parameters

LO2 **Describe the nature and effect of forces that act on aircraft in flight**

Factors effecting flight forces:

Wing plan form geometry and its effects on lift and drag production Boundary layer effects on lift and drag and its control

Atmospheric events: severe air turbulence, frost and ice accretion

Aero-elastic effects: wing torsional divergence, controls reversal and flutter

Nature of flight forces:

Lift/weight, drag/thrust, forces and couples, line of action, airspeed

Determine gravitational and aerodynamic forces during, straight and level flight, steady coordinated turn, climbing and diving flight, glide, pull-up, push-over manoeuvres

Manoeuvre envelope and structural limits, interpretation and consequences of exceeding limits

LO3 **Demonstrate the nature of high speed airflows and their effect on fixed wing aircraft design**

Nature of high speed airflows:

Speed of sound definition and relationship for a perfect gas ($a=\sqrt{\gamma RT}$), relationship between speed of sound and Mach number ($M=V/a$)

Nature of transonic and supersonic airflows over aerofoil sections, compressibility effects, shockwave formation, the shock stall, airflow parameters across the shockwave, Mach cone

Effects on fixed-wing aircraft design:

Problems with flight in the transonic range, shock stall effects, pitching and buffeting, transonic drag rise at constant lift, effect on flow rate, pressure, lift, drag, pitching moment and aerodynamic centre

Transonic flow and aircraft design: conventional, thin and supercritical wing sections, swept wings, load distribution, wing tip flow and design, transonic airflow over fuselage/wing and use of area ruling

Supersonic flow and aircraft wing plan form design, un-swept and swept wings, leading and trailing edge sweep back, swing-wing, swept forward wings

LO4 **Investigate the nature and methods used to control and stabilise fixed-wing aircraft**

Flight control:

Control requirements, aircraft axes, roll, yaw, pitch, six degrees of freedom

Primary conventional control surfaces: aileron, elevator and rudder, servo-tabs,balance-tabs, trim-tabs and q-feel control

Secondary controls: slab, all-moving tailplanes, canard surfaces, vee-tail, spoilers,high speed ailerons, flaperons, elevons

Lift augmentation and drag inducing devices: flaps, slats, slots, vortex generators,wing fences, winglets, spoilers and airbrakes

Aircraft stability:

Nature of static and dynamic stability: reaction to a disturbance for stable, neutrally stable and unstable bodies

Longitudinal static stability: trim, use of tailplane, pitching moments and significance of centre of pressure movement and centre of gravity limits, lateral static stability, yawing, rolling, stability methods and use of anhedral for inherentinstability

Longitudinal dynamic stability: nature and damping methods for short period pitching oscillations and phugoid motion, lateral dynamic stability, nature anddamping methods for spiral mode and Dutch roll

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Examine standard atmospheric properties and aerodynamic principles affecting flight		**D1** Analyse the properties of the air in the ISA, with changing altitude and the relationship between fluid flow equations and the generation of lift anddrag affecting flight
P1 Describe the nature of the ISA and the changes that take place to the properties of the air with changing altitude **P2** Assess, using theoretical calculations and experimental resultshow lift and drag forces are generated from low speed airflows over aerofoil sections	**M1** Explore quantitatively, how the properties of the air in the ISA change with altitude and the differences between the lift and drag forces foundfrom theoretical calculations and from experimental results	
LO2 Describe the nature and effect of forces that acton aircraft in flight		**D2** Evaluate the effect and nature of flight forces on the aircraft airframe, throughout all phases and conditions offlight, including the nature and significance of the load limits, within the manoeuvre envelopethat protect the aircraft structure
P3 Describe how wing planform, the boundary layer, atmospheric events and aero-elasticity, effect the generation and distribution of lift and drag **P4** Calculate the forces that act on aircraft in straight and level flight and during manoeuvres	**M2** Explore, using theoretical calculations the nature of flight forcesduring manoeuvres, how these forces are effected by geometrical and external factors and the significance of the manoeuvre envelope in protecting the aircraft structure	

Pass	Merit	Distinction
LO3 Demonstrate the nature of high speed airflowsand their effect on fixed wing aircraft design		**D3** Analyse transonic and supersonic airflows over aerofoil surfaces and the resulting problems, design features and their interrelationship, for aircraft that fly at transonic and supersonicspeeds
P5 Discuss the relationship between the speed of sound and Mach number and the nature of transonicand supersonic airflows over aerofoil surfaces **P6** Describe the problems with aircraft flight in the transonic range and the resulting design features for aircraft that fly at transonic and supersonic speeds	**M3** Explain transonic and supersonic airflows over aerofoil surfaces and the resulting problems and design features for aircraft that fly at transonic and supersonicspeeds	
LO4 Investigate the nature and methods used tocontrol and stabilise fixed-wing aircraft		**D4** Analyse aircraft control and stabilisation devices and methods and their interaction, for aircraft that fly in the transonic and supersonicspeed range
P7 Explore the nature and operation of aircraft primary controls and secondary controls, lift augmentation and drag inducing devices **P8** Describe the nature of static and dynamic stability and how aircraft are stabilised about their axes of rotation	**M4** Illustrate aircraft control and stabilisation devices and methods and their interaction	

Recommended Resources

Textbooks

ANDERSON Jr, J. D. (2016) *Introduction to Flight*. 8th International Student Ed.McGraw-Hill.

BARNARD, R. H. and PHILPOTT, D. R. (2010) *Aircraft Flight*. 4th Ed. Pearson.

DINGLE, L. and TOOLEY, M. (2013) *Aircraft Engineering Principles*. 2nd Ed. Routledge.

Journals

Aerospace (the magazine of the Royal Aeronautical Society), with articles on all areas of aerospace including innovation and design for flight.

The Aeronautical Journal. Cambridge University Press. Covering all aspects ofaerospace engineering and research.

Websites

http://www.av8n.com/	AV8N See How It Flies (E-Book)

Links

This unit links to the following related units:

Unit 28: Turbine Rotary Wing Mechanical and Flight Systems

Unit 56: Aircraft Propulsion Principles and Technology

Unit 55: Aircraft Flight Control Systems

Unit code F/615/1532

Unit level 5

Credit value 15

Introduction

The need to control aircraft during all phases of flight has become ever more sophisticated as the complexity, size and flight speed of aircraft have increased. This has led to developments that increase the functionality, power output, fault tolerance and integration of the systems that provide flight control. With each aircraft generation, flight control system design has developed from simple manual and power-assisted mechanical systems, through to hydraulically and/or electrically powered and on to the advanced computer-controlled fly-by-wire and automatic flightcontrol systems that we see today.

This unit will cover the design, development and operation of flight control systems for fixed wing aircraft through the generations and introduces students to the design,development and operation of mechanical, hydraulic power and fly-by-wire systems, and automatic flight control in the form of autopilot and autoland systems.

On successful completion of this unit students will be able to determine the construction, layout and operation of mechanical flight control systems and control surfaces, examine the design and operation of fly-by-wire flight control systems, determine the functions and operation of autopilot and autoland flight control systems and determine the contribution made to safe flight control by each system.

Learning Outcomes

By the end of this unit students will be able to:

1 Determine how the construction, layout and operation of mechanical flightcontrol systems contribute to safe flight control

2 Investigate how the design and operation of hydraulic powered flight control systems contribute to safe flight control

3 Investigate how the development and operation of fly-by-wire flight controlsystems contribute to safe flight control

4 Show how the functions and operation of autopilot and autoland flight controlsystems contribute to safe flight control.

Essential Content

LO1 Determine how the construction, layout and operation of mechanical flight control systems contribute to safe flight control

Flight control:

Control requirements; control about aircraft axes, roll, yaw and pitch control, sixdegrees of freedom, control loads, artificial feel and trim

Flight control surfaces, construction and aerodynamic operation: primary controlsurfaces, aileron, elevator, rudder; servo-tab, balance tab, trim tab; secondary control surfaces and devices, flap, slat, slot, flaperon, elevon, spoiler, vee-tail ruddervator

Mechanical flight control systems and their components:

Construction, function and layout of mechanical control system components:control column, wheels and levers, chains and sprockets, push/pull rods, bellcrank levers, torque tubes, spring feel units, control cables, pulleys, cable tensioner, turnbuckles, fairleads

Pilot input and system response, push/pull control rod and cable and pulleysystems

LO2 Investigate how the design and operation of hydraulic powered flight control systems contribute to safe flight control

Hydraulically powered flight control system component design and operation:

System requirements: sufficient power for control actuation, control surfacerigidity, need for trim actuation, artificial (Q) feel, stall warning, redundancy provision

Constructional design, function and operation of system major components: (Q) feel unit, trim actuator, hydraulic stick shaker; servo operated powered flying control unit (PFCU), hydro-mechanical power assisted and fully power operated PFCU, mechanically signalled hydraulic motor driven screw jack, electro-hydraulicPFCU

Design architecture and operation of hydraulically powered flight control systems:

Hydro-mechanical and electro-hydraulic powered flying control systems: pilotinputs and system response; PFCU servo actions, inputs, outputs, closed loopfeedback; system redundancy provision for primary and secondary control surface operation

LO3 Investigate how the development and operation of fly-by-wire flight control systems contribute to safe flight control

Fly-by-wire (FBW) control system development:

Introduction of electronically controlled, hydraulically and electrically poweredactuators

Solid state electronics for actuator control, pre-programmed computers for thecontrol and integration of primary and secondary flight controls functions

Benefits resulting from FBW control: improved flight handling, reduction in airframe weight and control size, integration of flight control functions, flightenvelope protection and alerting

Present and future benefits of fly-by-light (FBL) system signalling and control: further weight reduction from use of fibre-optic cabling and reduced componentsize, improved redundancy provision through system multiplexing

Operation of FBW systems and components:

FBW powered flight control unit (PFCU) operation: electro-hydraulic and electro-mechanical actuators, pilot side stick and conventional controls inputs, hydraulicservo operation, hydraulic and electrical feedback, redundancy provision

FBW system control and operation: operating modes, pilot and autopilot signal conditioning, closed-loop control, transducers and feedback circuitry; computerfunction, architecture, inputs and outputs for FBW controls integration

LO4 Show how the functions and operation of autopilot and autoland flight control systems contribute to safe flight control

Autopilot functions and operation:

Autopilot functions: maintenance of desired flight path and flight direction, pitchroll and yaw control

Autopilot servo-system operation: principles; error sensing inputs, correction, feedback and commanded outputs; circuitry signalling and actuation; input signals via transducers, error signal detection using electrical amplifiers, controlsurface actuation via servo-motor, position feedback signals to error detector amplifier

Autopilot operation for pitch, roll and yaw control; pitch damping and altitudehold, vertical speed and level change commands; roll heading and navigation modes; yaw damper signalling, rudder servo motor action

Automatic landing system functions and operation:

Instrument landing systems (ILS): function of aircraft and airfield navigation aids, automatic direction finder (ADF), distance measuring equipment (DMS), VHF omnidirectional range (VOR), during final approach, localiser and glideslope modes

Fully automatic landing system enhanced functionality and operation: functionality; radio altimeter, auto-throttle, enhanced ILS beam control laws, crosswind correction, continuation of runway flight guidance, go-round facility,continuous instrument display and monitoring; operation, during the approach,glideslope and landing phases of flight

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Determine how the construction, layout andoperation of mechanical flight control systems contribute to safe flight control		**D1** Analyse the function, layout and operation of mechanical flight control systems and components, assessing the contribution made by the system to safe flight control
P1 Discuss the control of fixed wing aircraft about their axes of rotation **P2** Investigate the function, layout and operation of mechanical flight control systems and components	**M1** Explore the function, layout and operation of mechanical flight control systems and components, identifyingthe contribution made by the system to safe flight control	
LO2 Investigate how the design and operation of hydraulic powered flight control systems contributeto safe flight control		**D2** Analyse the function, layout and operation of hydro-mechanical and hydro-electric powered flight control systems andtheir components, assessing the contributionmade by each system to safe flight control
P3 Discuss the design and operation of hydraulically power flight control system components **P4** Illustrate the design and operation of hydro-mechanical and electro-hydraulic powered flight control systems	**M2** Explore the design and operation of hydro-mechanical and hydro-electric powered flight control systems and their components, identifying the contribution made by each system to safe flight control	

Pass	Merit	Distinction
LO3 Investigate how the development and operationof fly-by-wire flight control systems contribute to safe flight control		**D3** Show how the development and operationof fly-by-wire control systems and components has contributed to safe flight control
P5 Discuss the development and benefitsof fly-by-wire control systems and components **P6** Illustrate the operationof fly-by-wire control systems and components	**M3** Justify the development and operation of fly-by-wire control systems and components, identifying the contribution made by these systems to safe flight control	
LO4 Show how the functions and operation ofautopilot and autoland flight control systems contribute to safe flight control		**D4** Assess how the functions and operation of modern autopilot, instrument and fully automated landing systems and components, assessing the enhanced functions thatcontribute to safe flight andlanding control
P7 Discuss the functions and operation of a modern autopilot system and components **P8** Illustrate the functions and operationof modern instrument and fully automated landing systems and components	**M4** Explore the functions and operation of modern autopilot, instrument and fully automated landing systems and components, identifying the enhanced functions that contribute to safe flight and landing control	

Recommended Resources

Textbooks

MOIR, I. and SEABRIDGE, A. (2008) *Aircraft Systems: Mechanical, Electrical and Avionics Subsystems Integration (Aerospace Series)*. 3rd Ed. Chichester: Wiley.

WYATT, D. (2015) *Aircraft Flight Instruments and Guidance Systems.* 1st Ed. Routledge.

Journals

Aerospace (the magazine of the Royal Aeronautical Society), with articles on all areas ofaerospace including the latest innovations on the design of fly-by-wire and fly-by-light flight control systems.

Websites

https://www.faa.gov Federal Aviation Administration Advanced Avionics Handbook(E-Book)

Links

This unit links to the following related units:

Unit 24: Aircraft Aerodynamics

Unit 59: Aircraft Gas Turbine Engine Design and Performance

Unit 56: Aircraft Propulsion Principles and Technology

Unit code J/615/1533

Unit level 5

Credit value 15

Introduction

No matter what method of propulsion is used to propel aircraft through the air, they all rely on the principle laid down in Newton’s third law, which states in its simplest form that to every action there is an equal and opposite reaction. The action force which we know as thrust may be provided by aircraft propellers or by the fluid streamfrom a jet engine exhaust, or by a combination of both.

This unit introduces students to the thermodynamic and mechanical principles thatunderpin aircraft propulsion and to gas turbine engine and piston engine construction, function and operation, as well as to the layout and operation of theirassociated components and support systems.

On successful completion of this unit students will be able to determine how thermodynamic and mechanical properties are applied to aircraft propulsion, and examine the construction, function and operation of gas turbine engines, their fluid,control and monitoring systems and piston engines and systems.

Learning Outcomes

By the end of this unit students will be able to:

1 Determine how thermodynamic and mechanical principles are applied to aircraft propulsion.

2 Examine the construction, function and operation of gas turbine engines and components.

3 Examine the layout, function and operation of the fluid control and monitoringsystems of gas turbine engines.

4 Describe the construction, function and operation of piston engines and systems.

Essential Content

LO1 Determine how thermodynamic and mechanical principles are applied to aircraft propulsion

Thermodynamic principles applied to combustion engines:

The gas laws and the expansion and compression of perfect gases, constantvolume, constant pressure, isothermal, adiabatic and polytropic processes

First law of thermodynamics applied to closed and open systems, non-flow (NFEE) and steady flow (SFEE) energy equations, concept of enthalpy in open systems, second law of thermodynamics applied to heat engines, measure ofthermal efficiency

Thermal cycles and the concept of entropy, use of pressure-volume and temperature-entropy diagrams, the Otto cycle for spark ignition piston engines,the Joule constant pressure cycle for gas turbine engines

The practical four-stroke cycle for piston engines, performance indicators,indicated and brake power, engine thermal efficiency

The practical closed and open gas turbine cycle, losses compared with the idealJoule cycle; thermal and propulsive efficiencies and measure of specific fuel consumption in aircraft gas turbine engines

Mechanical principles applied to fluid flow and propulsive thrust:

Newton's laws of motion applied to fluid flow; momentum and kinetic energy offluid flow, use of continuity, Bernoulli equation and SFEE for incompressible gasflows; compressible sonic flows, Mach number and airflow velocities, static and stagnation conditions, jet nozzle flow, chocked nozzles

Newton's laws and aircraft thrust from gas stream; gross thrust, intake dragforce, net thrust, net thrust with pressure thrust, thrust power; propeller aerodynamics and thrust production

Appropriate calculations to support principles detailed above

LO2 **Examine the construction, function and operation of gas turbine engines and components**

Types, construction and operation of gas turbine engines:

Turbojet engine: construction, arrangement and location of engine components and associated gearing and connections; operation, changes to the working fluidand the production of thrust as air/gas flows into the intake and through the compressor, combustor, turbine, propelling nozzle and exhaust components of the engine; operational limitations of the pure jet engine, noise pollution, reduced propulsive efficiency

Turbofan engine: construction, arrangement and operational differences between multi-shaft high bypass turbofan engines and the single shaft turbojet;relative advantages of turbofan engines over turbojets, fuel and propulsive efficiency, cooling and noise reduction

Turboprop engine: construction, arrangement and component location, additionof low-pressure turbine, main gearbox and propeller; operational differences in the production of thrust via a propeller; relative advantages/disadvantages over turbofan engines

Turboshaft engine: construction, arrangement and component location, introduction of larger diameter drive shaft and more robust compressors andturbines; operation for the production of torque to drive helicopter rotors; relative advantages in the use of this type of engine

Function and operation of gas turbine engine components:

Function and operation of compressors: axial flow compressors, stage rotors andstators, working fluid temperature and pressure rises and governing factors, inletguide vanes, variable stator vanes; centrifugal compressors, inlet duct and vanes,the impeller, rotating guide vanes and radial diffuser vanes, airflow pressure rise and centrifugal action

Function and operation of fans: compression of bypass air, supercharged air feed into core, need for multi-stage fans and form of fan blade, disc, attachmentsand casing

Combustors: types, multiple combustion chamber, tubo-annular and annular; requirements, high combustion efficiency, reliable ignition, restart facility, low- pressure losses and emissions, high durability; function and operation, control ofcombustible gases, fuel injectors, vaporisers, spray nozzles, ignitors and combustion chamber cooling

Function and operation of turbines: single and multi-stage, impulse and reactionturbines, energy transfer from the working fluid, turbine casing, discs, shafts andnozzle guide vanes, turbine cooling and constructional materials limitations

Function and operation of intakes and exhausts: intakes, bell-mouth, circular, variable geometry, drag minimisation at cruise speeds, integration with enginecowlings; exhausts, gas exhaust propelling nozzles, reverse thrusters, thrust vectoring nozzles, after burners

Appropriate calculations to support principles detailed above

LO3 **Examine the layout, function and operation of the fluid control and monitoring systems of gas turbine engines**

Layout and operation of turbine engine fluid systems:

Engine fuel systems: airframe and engine fuel system interaction requirements, avoidance of fuel contamination and suction operation, priming, re-priming andrelight facilities; component identification, function and layout; function and operation of typical engine fuel system including operation of hydro-mechanicalfuel meeting unit

Engine lubrication systems: lubricant types, properties, identification and use of additives; oil system functions; function and layout of lubrication system components; operation of recirculatory lubrication systems, pressure relief and full flow systems and pressure feed and distribution, scavenge and vent sub- systems

Internal air systems: functions cooling, sealing and bearing load control; functionand operation of air cooling system; identification, functions and nature of air system seals and sealing methods

Function and operation of engine control and monitoring systems:

Engine electro mechanical control systems: function and operation of mechanicalcables, rods and pilot control levers, electrically actuated valves and switches; function and operation of auto-throttle, regulation and switching, flight/ground idle control

Electronic engine control systems: identification and function of typical electroniccontrol system components, electronic controller, demand and feedback sensors, fuel pumps and fuel metering controller; function and operation of FADEC system, electronic engine controller (EEC), fuel metering unit (FMU) and fuel control monitoring

Engine performance and condition monitoring systems: instrumentation and measurement of engine temperature, pressure ratio, rotational speed and thrustperformance parameters; vibration and lubrication condition monitoring, use of magnetic chip detectors

LO4 **Describe the construction, function and operation of piston engines and systems**

Piston engine construction, operation and installation:

Engine construction and operation: crankcase, crankshaft, cylinder and piston assemblies, valve mechanism and timing, accessory and propeller reduction gearboxes, two and four stroke cycle operation, power and efficiency parametersand their monitoring and measurement

Power plant installation: configuration and function of firewalls, cowlings,acoustic panels, engine mounts, anti-vibration mounts

Function and operation of piston engine fluid, ignition and control systems:

Engine fuel and fuel metering systems: fuel system requirements, fuel meteringdevices; carburation principles, float and pressure injection carburettors, automatic mixture control; fuel-injection systems, fuel injectors and pumps, airflow/fuel regulation and metering; supercharged induction systems, turbochargers and their control

Lubrication systems: functions, types and characteristics of engine oil lubricants; lubrication system requirements; combined splash and pressure lubrication; dry and wet sump lubrication system components and operation

Engine ignition, control and starter systems: magneto-ignition principles, circuitoperation and components; full authority electronic digital control (FADEC) system operation and function of electronic control unit (ECU), booster coil, impulse coupling and retard breaker vibrators; inertia starters, direct cranking electric starter system operation and monitoring

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Determine how thermodynamic and mechanicalprinciples are applied to aircraft propulsion		**D1** Analyse the thermodynamic and mechanical principles applied to the operating cycles and production of propulsive thrust by piston-propeller and gas turbine engine driven aircraft, assessing the relative merits of each method of propulsion
P1 Describe the thermodynamic principles applied to reciprocating piston engine and aircraft gas turbine engine operating cycles **P2** Describe the mechanical principles applied to the productionof propulsive thrust by piston-propeller and gas turbine engine driven aircraft	**M1** Explain, with the useof calculations, the thermodynamic and mechanical principles applied to the operating cycles and production of propulsive thrust by piston-propeller and gas turbine engine driven aircraft, identifying the relative merits of each method of propulsion	
LO2 Examine the construction, function and operationof gas turbine engines and components		**D2** Analyse the constructional features, function and operation of turbojet, turbofan, turboshaft and turboprop gas turbine engines and their components, assessing the relative performance of each engine and component arrangement
P3 Illustrate the construction and operation of turbojet, turbofan, turboshaft andturboprop gas turbine engines **P4** Describe the functionand operation of gas turbine engine, intake, compressor, combustor,turbine and exhaust components	**M2** Explore the construction, function and operation of turbojet, turbofan, turboshaft and turboprop gas turbine engines and their components, identifying, with calculations, the relative performance of each engine type	

Pass	Merit	Distinction
LO3 Examine the layout, function and operation of thefluid control and monitoring systems of gas turbine engines		**D3** Analyse the layout and operation of engine, fluid, control and monitoring systems and assess the effect that theoperation of their major components has on eachsystem
P5 Illustrate the layout and operation of engine fuel, lubrication and internal air fluid systems **P6** Describe the function and operation of engine electro-mechanical, electronic and FADEC control systems and engine monitoring systems	**M3** Explain the layout and operation of engine, fluid, control and monitoring systems and the function and operation of the major components for each system	
LO4 Describe the construction, function and operationof piston engines and systems		**D4** Evaluate the constructional features and operation of aircraft reciprocating piston engines and their associated ancillaries and supporting systems, assessing the operational benefits for the choice and layout of the major components, for each supporting system
P7 Describe the construction, operation and installation of aircraft reciprocating piston engines **P8** Illustrate the functionand operation of engine fuel, lubrication, ignition,control and starter systems	**M4** Explore the construction and operation of aircraft reciprocating piston engines and their supporting systems, identifying the function and layout of the major components, for each supporting system	

Recommended Resources

Textbooks

Royce, R. (2015) *The Jet Engine*. 5th edn. Chichester, West Sussex: John Wiley & Sons.

SARAVANAMUTTOO, H. I. H., ROGERS, G. F. C., COHEN, H., STRAZNICKY, P. V. (2009) *Gas Turbine Theory*. 6th Ed. Pearson.

TOOLEY, M., and DINGLE, L. (2012) *Engineering Science, Part III*. Routledge.

Journals

The Aeronautical Journal. Cambridge University Press. Covering all aspects of aerospace.

Links

This unit links to the following related units:

Unit 13: Fundamentals of Thermodynamics and Heat Engines

Unit 38: Further Thermodynamics

Unit 60: Advanced Composite Materials for Aerospace Applications