MQF Level 7

AM7-01-21

Master of Science in Aerospace Engineering

Course Specification

Course Description

The MSc in Aerospace Engineering aims to form graduates that will be able to design and implement aerospace projects, focusing on more productive but environmentally friendly technologies; so as to respond to the today's challenge of a cleaner sky and less noisy and non-polluted environment, as well as to develop safer, faster and cheaper transportation for a growing society. This Master course objective is to provide to the graduates the skills required by national and international aerospace companies and with the right profile to match recruitment criteria for agencies as well as public and private bodies in the aerospace sector and also other engineering sectors, for example Automotive. In detail, MCAST highly targeted learning aerospace pathway aims at developing career-enhancing skills for aerospace professional in the aviation sector and in the expanding civilian space business in fields such as the management, maintenance and conversion of aircraft, R&D of technologies for new generations of aircrafts, and civilian applications for smart satellites and sub-orbital spacecrafts. The course offers the students the possibility to specialize in one of three most highly-demanded fields, such as: Structures and Measurements for Aerospace; Aerodynamics; Space Technologies.

Programme Learning Outcomes

At the end of the programme the students are able to:

1. *Apply knowledge of mathematics, science and engineering in aerospace to design and conduct experiments as well as to analyse and interpret data;*
2. *Design a system, component or process to meet desired needs and to function on multi-disciplinary teams in order to identify, formulate and solve engineering problems;*
3. *Use the techniques, skills and modern engineering tools necessary for engineering practice;*
4. *Understand aerodynamics, aerospace materials, structures, propulsion and competence in the integration of aerospace science and engineering topics and their application in aerospace vehicle design;*
5. *Form professionals that can communicate effectively and manage projects and teams;*
6. *Recognise professional and ethical responsibility.*

Entry Requirements

A Bachelor degree in Mechanical, Aerospace Engineering or related field from a recognized institution or an equivalent international qualification, validated by MFHEA, or MCAST Engineering Level 5 and 10 years of experience in a technical position in the aviation/aerospace industry.

Current Approved Programme Structure

Unit Code	Unit Title	ECTS	Year
Core Units			
ETACT-706-2113	Aircraft Propulsion	6	1
ETACT-706-2114	Aerospace Structures 1	6	1
ETACT-706-2115	Aviation Maintenance Management and Law	6	1
ETACT-706-2116	Aerodynamics 1	6	1
ETACT-706-2117	Measurements for Aerospace	6	1
ETACT-706-2118	Methodologies for Integrated Product Development	6	2
Elective 1: Specialisation in Structures and Measurements for Aerospace			
ETACT-706-2119	Aerospace Structures 2	6	2
ETACT-706-2120	Aerospace Engineering Materials	6	2
ETACT-706-2121	Mechanical FEA with Laboratory	6	2
ETACT-706-2122	Vibrations	6	2
Elective 2: Specialisation Aerodynamics			
ETACT-706-2123	Aerodynamics 2	6	2
ETACT-706-2124	Atmospheric Flight Dynamics	6	2
ETACT-706-2125	Technology for Sustainable Aviation	6	2
ETACT-706-2126	CFD with Laboratory	6	2
Elective 3: Specialisation Space Technologies			
ETACT-706-2127	Space Propulsion	6	2
ETACT-706-2128	Spacecraft Systems Design	6	2
ETACT-706-2129	Thermal Control of Aerospace Vehicles	6	2
ETACT-706-2130	Astrodynamics	6	2
Core Units			
ETACT-760-2131	Research Project (Final Thesis and Dissertation)	60	3
	Total ECTS	120	/

Unit: ETACT-706-2113- Aircraft Propulsion

Unit level (MQF): 7

Credits : 6

Unit Description

The development of aircraft is outstanding. December 1903 was the dawn of human-engineered flight thanks to the Wright Brothers. The number of passengers carried by commercial airlines exceeded 3.3 billion just once century after via more than 250,000 aircraft powered by more than hundred types of aero engines. Due to the rapid advance in air transportation as well as military and intelligence missions, aircraft and rocket propulsion has become an essential part of aerospace engineering education. Propulsion is the combined aero-thermal science for aircraft and rockets constituting both macro and microscales. Macroscale relates to the performance and operation of aircraft during different missions, whilst microscale is concerned with component design including both rotary modules, like compressor, fan, pump, turbine and stationary modules, like intake, combustor, nozzle, and afterburner.

More specifically, this unit provides the student with a deep understanding of aircraft propulsion systems in terms of classification, performance parameters of piston engines and propellers, jet engines, turbine-based engines, intakes, combustion systems and nozzles.

In summary, the selected study topics equip the student with the necessarily theoretical background to analyse aeronautical propulsive devices as systems, with their functional requirements and engineering limitations due to design choices. The unit enables the student to integrate the propulsive system with the overall vehicle design by performing thorough mission analysis and optimisation whilst employing fundamental performance relations.

Learning Outcomes

On completion of this unit the learner will be able to

1. *Discuss aircraft propulsion systems classification and main principles.*
2. *Describe jet engines and aircraft propellers.*
3. *Review of the different types of intakes, combustors and nozzles.*
4. *Describe the different parameters of compressors, turbines and solve design problems.*

Unit: ETACT-706-2114- Aerospace Structures 1

Unit level (MQF): 7

Credits : 6

Unit Description

The study of mechanics and structural analysis has been an important area of engineering over the past 300 years with some of the greatest minds contributing to its development. Sir Isaac Newton formulated the most basic principles of equilibrium in the 17th century, but fundamental contributions have continued well into the 20th century. Today, structural analysis is generally considered to be a mature field with well-established principles and practical tools for analysis and design. A key reason for this is, without doubt, the emergence of the finite element method and its widespread application in all areas of structural engineering. As a result, much of today's emphasis in the field is no longer on structural analysis, but instead is on the use of new materials and design synthesis.

The field of aerospace structural analysis began with the first attempts to build flying machines, but even today, it is a much smaller and narrower field as compared to the fields of structural analyses in civil and mechanical engineering.

This unit introduces students to the solution of real-world structural problems with some of the unique and challenging features of aerospace structures, which often involve thin-walled structures made of fibre-reinforced composite materials.

More specifically, this unit provides the student with an extended knowledge of the fundamentals of structural analysis, energy-method techniques for structural problems, plate bending and buckling theory, together with an overview of the structural components of aircraft.

The unit content is mainly oriented to aerospace applications but the knowledge by the end of this unit is significantly important to any engineer within the various industries.

In summary, the selected study topics provide the student with the necessary theoretical background to provide answers to challenges related to the complexities of designing solution techniques in aerospace, by putting into practice the fundamental notions of structural analysis.

Learning Outcomes

On completion of this unit the learner will be able to

1. *Discuss the fundamentals of structural analysis.*
2. *Review energy-method solution techniques for structural problems*
3. *Explain plate theory and the ability to use this to obtain analytical solutions for plate bending and buckling problems.*
4. *Analyse structural components of aircrafts.*

Unit: ETACT-706-2115- Aviation Maintenance Management and Law

Unit level (MQF): 7

Credits : 6

Unit Description

This unit will help learner understand how the management system of an aerospace engineering company operates. The learner will become aware that engineers are employed in many different businesses across a range of sectors and that the skills and knowledge of an engineer in this growing industry can be used across a variety of functions to solve and align to evolutionary and business needs and contribute to the overall commercial success. It is important that the learner understands how the aerospace engineering business operates and how it is placed within its economic sector. This unit aims to develop the learner in understanding business and the economy of how aerospace engineering organization are operating evolving inside supply chains and the environment. The learner will come to understand the changes that the cyber era is creating and how these technological advancements impact the viability of this important business sector.

It is important that the learner understands that these issues are not limited only to aerospace engineering organizations. The unit will allow the learner to look at a specific aerospace engineering company objectively to understand how it operates. It would be ideal if the learner was employed in an engineering company preferable an aerospace engineering company which is an essential element to understand the outcomes of this unit. The learner will come to understand how an aerospace engineering company functions within its sector and how it achieves its strategic aims and objectives. This will involve a clear understanding of how these companies works and the essential functions that ensures them success. The learner will become familiar with current quality assurance legislations and the constraints that these legislations place on an aerospace engineering company, including the external factors that impacts the way an aerospace engineering company is run. Also, in this unit, the learner will come to understand the relevant cost management techniques that are required by professionals to evaluate any innovative or creative research and design by deciding if these advancements can make economic sense or not in context of aggressive market competitions. Leadership styles are essential when it comes to lead an enterprise that involves highly intensive technological machinery. Contemporary modern management theories and techniques are therefore required to further impact the success of the business. Finally, this unit of study aims to create an awareness of issues surrounding the management of project planning and control, probabilistic risks and quality assurance auditing resulting in a more global approach to the practice of engineering and engineering management that provides a vehicle for improving communication skills (both written and oral).

Learning Outcomes

On completion of this unit the learner will be able to

1. *Establish management roles and contemporary leadership and management in the Fourth Industrial Revolution.*
2. *Analyse the general administrative and operations of an engineering company and how it can be affected by various external factors and the economic environment itself.*
3. *Evaluate the cost effectiveness of engineering activities by considering and applying cost management techniques.*
4. *Establish how Quality Assurance laws and regulations may increase constraints on an engineering activity that may have impacts on an engineering activity.*

Unit: ETACT-706-2116- Aerodynamics 1

Unit level (MQF): 7

Credits : 6

Unit Description

The primary aim of this unit is to provide students with a fundamental understanding of aerodynamic theory. This unit introduces students to the hierarchy and different branches of aerodynamics which will be covered in Aerodynamics 1 and Aerodynamics 2. An overview of the different flow models is given to set the picture on the types of flow that govern the various speed regimes. In this spirit, the usefulness of these flow models is explained whilst the main limitations and their range of applicability are highlighted.

More specifically, this unit mainly focuses on incompressible aerodynamics used to approximate fluid flow in the subsonic regime. Particular cases of inviscid, incompressible flow on aerofoils and simple wings such as potential flow, thin aerofoil theory and lifting line theory are explained. This unit then delves into the realm of viscous flow and boundary layer theory. The basic concepts and the fundamental governing equations are explained before providing a detailed understanding of the characteristics of laminar and turbulent flows, boundary layer transition and boundary layer separation. The theoretical understanding is complemented by practical sessions making use of scientific programming and computational tools used for inviscid/viscid flow analysis on aerofoils.

Learning Outcomes

On completion of this unit the learner will be able to

1. *Discuss the basic principles and hierarchy of aerodynamic theory together with the corresponding limitations and range of applicability of the respective methods.*
2. *Analyse the aerodynamic characteristics of aerofoils and simple finite wings.*
3. *Analyse the key characteristics of laminar and turbulent flows.*
4. *Use computational tools for the design and analysis of aerofoils and interpret the results.*

Unit: ETACT-706-2117- Measurements for Aerospace

Unit level (MQF): 7

Credits : 6

Unit Description

Mechanical measurements for aerospace comprise a branch of engineering encompassing a wide range of challenges in the ever-growing aviation and space industry. Measurements are used throughout the aerospace product lifecycle spanning processes such as: Manufacturing, quality control/testing, prototyping, research and development, fabricating, machining, and welding.

This unit develops topics related to device calibration, including the design of instrument and test facilities, avionics and instrumentation for aerospace. The interpretation of results and their applicability to the model are also discussed. Moreover, every space mission is based on the realisation of a number of physical models on which campaigns of measurements aimed to verification and qualification of the unit are performed.

Such methodologies are interdisciplinary and can be applied to various areas. These include vision system for measuring and control, no-contact deformation measurement, measuring techniques for diagnostics and quality control, no contact torque measuring techniques on engines and operative machines, measuring techniques of contact pressure distribution, opto-mechanical sensors for measuring mechanical quantities in medicine, and innovative measuring techniques for diagnostics in rotating shaft and metal tube.

More specifically, this unit provides the student with an extended knowledge of the measurement process, the analysis techniques for instrument characterisation, the ability to design a measurement chain according to the required performance, the ability to acquire, process and interpret parameters of static and temporal variables. The topics are mainly oriented to aerospace and aviation maintenance management, however, the knowledge of these topics is useful to any engineer working in the various industries.

In summary, the selected study topics provide the student with the necessary theoretical background to analyse and provide answers to challenges related to measurements of mechanical, thermal and electrical quantities by applying the fundamental notions of the measurement process and compiling lab reports, in compliance with current standards.

Learning Outcomes

On completion of this unit the learner will be able to

1. *Discuss the fundamental notions of the measurement process.*
2. *Review the analysis methodologies for determining the static and dynamic characteristics of the instruments.*
3. *Design a measurement chain according to the required performance.*
4. *Describe how to acquire, process and interpret parameters of static and temporal variables.*

Unit: ETACT-706-2118- Methodologies for Integrated Product Development

Unit level (MQF): 7

Credits : 6

Unit Description

Modern industries are shifting from the traditional over-the-wall method of product development to a more integrated and seamless development environment. The economic success of most firms depends on their ability to identify the needs of customers and to quickly create products that meet these needs and can be produced at a low cost. Achieving these goals is not only a marketing problem, a design problem or a manufacturing problem, but it is a product development problem involving all of these functions.

This unit introduces the current principles and philosophies of product development and realization, with the aim of familiarizing the learner with the importance of concurrent and collaborative engineering in a global economy and how to realize a collaborative design environment.

The methods presented apply to a broad range of products, including, for example, aerospace systems, scientific instruments, consumer electronics, machine tools, automotive systems and medical devices.

More specifically, the topics of this unit will span product specification and conceptual design through detailed and domain-specific design, including manufacturing process development.
The unit content is mainly oriented to describe the systematic concept development process, determine customer needs, identify product features through gathering product information and decomposing product.

In summary, the selected study topics provide the learner with the necessary theoretical background to provide answers to challenges related to the complexities of modern industries and customer requirements, by putting into practice the methodologies integrated product development.

Learning Outcomes

On completion of this unit the learner will be able to

1. *Examine the fundamentals of integrated product development.*
2. *Review the concept development phases.*
3. *Discuss the design of a product.*
4. *Evaluate the concept validation and prototyping.*
5. *Use computational tools for Product Lifecycle Management (PLM).*

Unit: ETACT-706-2119- Aerospace Structures 2

Unit level (MQF): 7

Credits : 6

Unit Description

This unit complements Aerospace Structures 1 and provides students with a deeper and more extended understanding of solutions for real-world structural problems.

Aerospace structures can be quite complex to analyze since they must respect several and often conflicting requirements: they must be light but resistant, durable and, above all, safe. For example, from a structural design point of view, these systems must be designed in order to accurately distribute the mass in the region where it is necessary, to avoid any unjustified weight increment leading to inefficiency. Moreover, the evaluation of structural plasticity is a critical aspect.

This unit aims to provide a familiarity with a design process analysis that can be tailored to meet the needs of individual projects and to introduce aerospace engineers to the complex interactions that need to be understood and managed in contemporary projects.

Emphasis is also placed on understanding the requirements that provide a product with technical excellence.

More specifically, this unit offers an understanding of the airworthiness of an aircraft, concerned with the standards of safety incorporated in all aspects of its construction, advanced learning of aeronautical structural analysis, an introduction to the finite element methods theory, together with an overview of spacecraft structures main loads.

In summary, the selected study topics offer the student the theoretical background on advanced topics in structural mechanics to provide answers to challenges related to the complexities of designing solution techniques in aerospace, by putting into practice the fundamental notions of structural analysis.

Learning Outcomes

On completion of this unit the learner will be able to

1. *Discuss the fundamental notions of airworthiness and airframe loads.*
2. *Review different types of loads on aeronautical structures.*
3. *Discuss the main principles of the finite element method.*
4. *Analyse the main loads on space structures.*

Unit: ETACT-706-2120- Aerospace Engineering Materials

Unit level (MQF): 7

Credits : 6

Unit Description

Aerospace engineering materials involves the study of the main types of materials used in the manufacture of aerospace structures and engines, the analysis of their properties and technological aspects of production.

The subject aims at developing competencies required in the selection of modern aerospace materials, equipment and quality control tools.

This Unit covers the fundamentals and engineering science of different types of aerospace materials, performance issues and materials selection for aerospace applications. Topics include manufacturing techniques, fatigue, loads and stresses, design considerations, inspection methods.

More specifically, this Unit provides the student with a deep understanding of the properties of aerospace materials, gives an overview of the different types used in the industry, provides the knowledge to make evaluations regarding the performances and material selection.

In summary, the selected study topics cover the necessary theoretical background to determine the key parameter for materials used in aircraft and spacecraft, evaluating design considerations and allowing to determine optimal material selection.

Learning Outcomes

On completion of this unit the learner will be able to

1. *Discuss the fundamentals of aerospace materials.*
2. *Describe the engineering science and properties of aerospace materials.*
3. *Review different types of aerospace materials.*
4. *Discuss performance issues and materials selection for aerospace structures.*

Unit: ETACT-706-2121- Mechanical FEA with Laboratory

Unit level (MQF): 7

Credits : 6

Unit Description

The finite element method has been a powerful tool for the numerical solution of a wide range of engineering problems. Applications range from deformation and stress analysis of automotive, aircraft, building, defense, missile, and bridge structures to the field analysis of dynamics, stability, fracture mechanics, heat flux, fluid flow, magnetic flux, seepage and other flow problems.

With the advances in computer technology and CAD systems complex problems can be modeled with relative ease. Several alternate configurations can be tried out on a computer before the first prototype is built.

The basic theoretical under pinnings in any particular engineering field is required to understand the behavior of any structure and a brief but essential theoretical review will be covered in this unit as an introduction.

Most often it is not possible to ascertain the behavior of complex continuous system without some sort of approximation. For simple members like uniform beams, plates etc., classical solutions can be sought by forming differential and/or integral equations. On the contrary structures like machine tool frames, pressure vessels, automobile bodies, ships, aircraft structures, domes etc, need some approximate treatment to arrive at their behavior, in static deformation, dynamic properties or heat conduction properties.

This motivates the content of this unit and is intended to give a hands on practical approach to problem solving in different domains with the use of popular software packages that can deal with multi-physics (cross-domain) problems.

Learning Outcomes

On completion of this unit the learner will be able to

1. *Solve problems related to bars, trusses, beams and plates.*
2. *Solve problems related to deflection in beams subjected to different loading and boundary conditions.*
3. *Solve 1D and 2D heat transfer problems with conduction boundary conditions.*
4. *Analyse natural frequencies for various boundary conditions and also forcing functions.*

Unit: ETACT-706-2122- Vibrations

Unit level (MQF): 7

Credits : 6

Unit Description

This unit first introduces the student to single-DOF systems, both free and forced systems together with vibration isolation related considerations. Once the introduction is covered, two-DOF systems undergoing both free and forced vibrations are examined. The analysis is extended further to Multi-DOF systems making use of linear algebra for modal analysis.

In the second part of the unit the student is introduced to different methods of solution, for example: Rayleigh, Stodola, Matrix iteration, Holzer and Dunkerley's methods.

In the third part torsional vibrations are considered as a special case, including analysis with geared and branching systems.

In the fourth part continuous systems are introduced and different solution techniques are presented. Case studies are analysed which can either have closed form solutions and others that can have only approximate solutions. This leads to an introduction to finite element analysis, with Galerkin's method for beams and also the formulation of the finite elements for rods.

The final part of the unit introduces the students to techniques like vibration signature analysis, use of probability density functions to evaluate structural relaibility and preventive maintenance with focus on different fields related to aerospace engineering like field balancing of rotors.

Learning Outcomes

On completion of this unit the learner will be able to

1. *Obtain analytical solutions to Two-DOF systems.*
2. *Evaluate natural frequencies of Multi-DOF systems using different methods.*
3. *Provide analytical solutions to Torsional Vibration systems.*
4. *Provide solutions to vibrating continuous systems.*

Unit: ETACT-706-2123- Aerodynamics 2

Unit level (MQF): 7

Credits : 6

Unit Description

This unit complements Aerodynamics 1 and provides extended knowledge of aerodynamic theory. The primary aim is to provide detailed understanding of compressible flow which is crucial to the design of commercial transport aircraft that operate in the transonic and supersonic flight regimes. This unit is aimed at students who want to specialise in aerodynamics.

In the first part, the introductory concepts related to compressible flow are first provided including thermodynamic concepts, speed of sound, Mach number and shock waves. Isentropic flow relations together with the differences between inviscid incompressible and compressible flows are then explained. The special cases of Rayleigh and Fanno flow are discussed in the context of ideal and real compressible flows.

The second part of the unit treats the important concept of shock waves and flow discontinuities. These are explained by first going through normal shock waves, normal shock relations and wave drag. The discussion on shock waves is then extended into oblique shock waves, oblique shock relations and Prandtl-Meyer expansion waves. The combination of these analytical theories is combined via the classical shock-expansion theory, whereby its strengths and weaknesses are highlighted. The various charts and look-up tables which can be used for these analytical solutions are introduced. The compressible flow theory that has been learned is then applied through the specific application of a converging-diverging nozzle, also known as the De Laval Nozzle. The theoretical relations and practical applications involving under-expanded and over-expanded nozzles are illustrated. Other concepts such as contact waves and contact surfaces, shock tubes, shock reflections and linearized flow are explained.

The third part of the module deals with applied aerodynamics, rather than fundamental aerodynamic theory, in the context of transonic aircraft design. The difference between subsonic and transonic flight is explained together with the various considerations in aerofoil design. Having discussed transonic aerofoils, the unit proceeds to finite wings including general design techniques such as the transonic area rule. The fundamental importance of swept wings is explained together with performance and drag assessment methods.

Learning Outcomes

On completion of this unit the learner will be able to

1. *Discuss wave propagation and the fundamental concepts of compressible flow.*
2. *Analyse compressible flow problems making use of the appropriate theory.*
3. *Apply compressible flow theory for the specific application of a converging-diverging nozzle.*
4. *Examine the particularities of transonic flow and the characteristics of transonic wings and aerofoils.*

Unit: ETACT-706-2124- Atmospheric Flight Dynamics

Unit level (MQF): 7

Credits : 6

Unit Description

The aim of this unit is to provide students with the fundamentals and the principles of flight dynamics in normal atmospheric flight. The subject of flight dynamics relates to the dynamics, stability and control of an aircraft together with complex interactions between the airframe and the flight control system. The modern approach to this subject is to treat the airframe as a system component enabling a linear systems approach to aircraft stability and control. This unit complements the theoretical concepts with practical exercises making use of scientific programming.

The first step is to present the foundations to allow the systematic and orderly implementation of mathematical models. These include the various reference axes and the appropriate choice of axes, transformations and a description of the geometric layout of aircraft. The notation and sign convention related to aerodynamics and propulsion controls are introduced together with a recap on aerodynamic concepts and reference centres. The important concept of the steady trimmed flight condition is described in detail. At this point, the concept of static stability is introduced before going into longitudinal static stability and the pitching moment equation. A description of the pilot control actions to trim is given in this context before introducing lateral-directional stability and directional stability.

The second part of this unit regards the equations of motion. The generalised six degrees of freedom equations of motion of a rigid symmetric airframe are developed in order to introduce the concept of linearised equations for longitudinal symmetric motion and lateral-directional asymmetric motion. The derived equations are then presented in state space form to describe the airplane as a linear dynamic system under the assumption of small perturbations. The discussion then shifts to the solution of these equations of motion. The dynamic relationships between the input and the output variables are explained through the aircraft response transfer functions and state-space models and model augmentation.

Having solved the equations of motion, the last part of the unit entails flight dynamics. More specifically, a detailed description of dynamic stability modes, reduced-order models and the frequency response is given for the longitudinal and lateral-directional dynamics, respectively. The aim here is to explain the fundamental role of stability modes in determining the flying and handling qualities of an aircraft. An introduction to manoeuvring flight together with aircraft stability and handling is provided in the context of flying and handling quality requirements. The graphical interpretation of stability and root mapping on the s-plane. Finally, stability augmentation and control systems are introduced in the context of improving the aircraft dynamic modes and its control response.

Learning Outcomes

On completion of this unit the learner will be able to

1. *Derive and solve the equations of motion for a conventional aircraft.*
2. *Explain the dynamic stability modes and their relation to the flying and handling qualities of an aircraft.*
3. *Discuss the relationships between geometric, inertial and aerodynamic features to control inputs.*
4. *Design simple control systems to improve aircraft stability, flying and handling qualities.*

Unit: ETACT-706-2125- Technology for Sustainable Aviation

Unit level (MQF): 7

Credits : 6

Unit Description

This unit addresses the challenge of modern civil aviation to meet growing passenger demand whilst becoming cheaper, cleaner and safer. Notwithstanding the exceptional decline during the COVID-19 pandemic, global air travel is forecasted to continue increasing such that its environmental impact is a critical issue. Therefore, the development of sustainable technology is essential in order to meet stricter environmental targets.

The first part of this unit presents the role of aviation as a mode of by contemplating the efficiency of modern aircraft when compared to other transportation methods. The impact of aviation in the context of local air quality, noise and climate change is addressed. The contribution of greenhouse gases and the implications on the global radiation balance and the greenhouse effect is then discussed. Then, the commercial drivers for aviation are reviewed within the realm of sustainable transport. This leads to a discussion on economic considerations in airline operations which entails a high ratio of revenue generated to revenue cost. Concepts including the ratio of energy liberated to revenue work done, coefficient of environmental performance, fuel burn, propulsive efficiency, the Bregeut range equation, and the mass breakdown of aircraft together with payload are explained. Having introduced the theorems on these concepts, ways to reduce structural weight and fuel burn are illustrated through novel research themes. In this spirit, the importance of aerodynamic efficiency is demonstrated by delving into traditional and alternative aircraft configurations, types of flow control, composite structures, and morphing wings.

The second part of the unit deals with contrails, aircraft noise and wake vortices. The discussion on contrails comprises their effect and concerns, their formation and finally their mitigation. The section on aircraft noise provides a historical evolution on this topic, current trends and the ACARE 2050 flight path targets. Introductory concepts of aeroacoustics are then discussed including noise metrics, the signatures of noise, airframe noise, engine-specific noise, bluff bodies, bio-inspired wings and noise certification. With regards to wake vortices, the phenomenon of wake vortex encounters and their consequences are considered. This includes the influence on air traffic management and runway utilisation. At this stage, the overarching concepts of aircraft operations and ways to mitigate their effect on the environment are discussed including direct routing, contrail avoidance, multi-stage travel, air-to-air refuelling and formation flying. The last part of the unit gives a qualitative description of the aerodynamics of vortex flows and a summary on vortex models.

Learning Outcomes

On completion of this unit the learner will be able to

1. *Discuss the importance of developing modern sustainable technology that meets increased capacity whilst reducing environmental impact.*
2. *Apply theoretical relationships for the economic considerations in aircraft operations and the relative impact of key engineering designs.*
3. *Explain the phenomenon of contrails and their mitigation.*
4. *Describe the basics of aeroacoustics and the impact of aviation on noise pollution.*
5. *Discuss the implications of wake vortices and the surrounding aerodynamic theory on vortex flows.*

Unit: ETACT-706-2126- CFD with Laboratory

Unit level (MQF): 7

Credits : 6

Unit Description

This unit provides the interested student with the fundamentals of fluid dynamics and the corresponding numerical simulation techniques to understand the workflow of modern computational fluid dynamics (CFD) processes. The main idea is to give a detailed overview on CFD with special focus on aerospace applications. In other words, the aim is to equip students with the fundamental knowledge to be able to design a CFD process in an applied aerodynamics setting by going through the fundamental theory and practical applications. This overview spans across the governing equations, grid generation, numerical methods, the classification and types of fluid flow, turbulence, and the post-processing and visualisation of results.

More specifically, in the first part the fundamentals of fluid dynamics including ways to describe flows, conservation laws, physical assumptions and the closure problem are introduced. The theoretical fluid dynamics are explained within the context of CFD to give an appreciation of the benefits and challenges of computational tools. Having introduced the fundamental principles, the focus shifts to geometry modelling, methods of grid generation and adaptation, and the assessment of grid quality. This topic precedes the principles of numerical methods whereby spatial and temporal discretisation, boundary conditions and the ways to solve partial differential and algebraic equations are described in detail.

The second part of the unit discusses the fundamental concepts of turbulence and instabilities together with their mathematical modelling. The principles of the structure of turbulence and the turbulent boundary layer, turbulent scales, wall units, energy scales and dissipation are explained. The Navier-Stokes equations are revisited in the context of the closure problem in order to introduce the modelling hierarchy and the realm of turbulence modelling. At this stage, the classification of low-speed and high-speed flows is explained in order to focus on the numerical methods that are employed to simulate each type of flow. The idea is to provide a conceptual understanding of these numerical methods used in the computation incompressible and compressible flows. This part of the unit covering the different types of flow solvers and numerical schemes is adapted to go through those which are used in the practical part of the unit.

The third part of the unit deals with the final part of the CFD process, that is, the post-processing and visualisation of results and their verification and validation. An important aspect here is the consistent visualisation of results allowing qualitative assessment of the flow together with comparative quantitative comparison. Furthermore, several ways to visualise the flow are introduced such as contours, vectors, iso-surfaces and iso-volumes, streamlines/streaklines/pathlines and vortex detection criteria including vorticity, the Q-criterion and Lambda2. Methods to analyse large volumes of unsteady data, increasingly becoming popular due to the ever-increasing computational power, are also discussed. Lastly, the principles of verification and validation are described.

Learning Outcomes

On completion of this unit the learner will be able to

1. *Discuss the foundations of computational fluid dynamics and the governing equations as typically formulated in commercial software.*
2. *Analyse the various phases of the CFD process.*
3. *Apply suitable numerical methods for the computation of incompressible and compressible flow in aerospace applications.*
4. *Assess results objectively and consistently both from a qualitative and quantitative perspective.*

Unit: ETACT-706-2127- Space Propulsion

Unit level (MQF): 7

Credits : 6

Unit Description

The development of space launchers and rocket propulsion systems is allowing space exploration from the Earth's orbit towards the Solar System, whilst enabling orbital satellites to continuously transform human civilisation. The recent upsurge in global government and private investment into space-flight initiatives has resulted in many novel applications of rocket propulsion technology.

This Unit discusses the fundamentals and advanced concepts in space propulsion together with rocket propulsion ranging from chemical to electrical engines. Topics include rocket performance parameters, the rocket equation, mission analysis and the different types of propellants.

More specifically, this unit provides the student with a deep understanding of the dynamic thermofluid concepts surrounding rocket propulsion. This unit also aims to give an overview of current and future space propulsion systems. Sufficient breadth is provided to the student to implement basic calculations of propulsion systems whilst appreciating the applicability of different space propulsion concepts.

In summary, the selected study topics provide the student with the required theoretical background to do a rational integration of the propulsive system into an overall design with proper mission analysis, using fundamental performance relations to determine optimal design solutions.

Learning Outcomes

On completion of this unit the learner will be able to

1. *Discuss space propulsion thermofluid dynamic fundamentals.*
2. *Explain space propulsion systems and performance.*
3. *Analyse different types of space propulsion engines.*
4. *Examine the preliminary design of a space propulsion system.*

Unit: ETACT-706-2128 - Spacecraft Systems Design

Unit level (MQF): 7

Credits : 6

Unit Description

Spacecraft system design involves the study of methods and techniques necessary for the development of aerospace sub-systems and their components, according to the requirements to be fulfilled in terms of mission profile.

Man has only had the ability to operate spacecraft successfully since 1957, when the Russian Sputnik I was launched into orbit. In a few decades technology has made great strides and unmanned explorer spacecraft have flown past all the major bodies of the solar system. Vehicles have landed on the Moon, Venus and Mars, moreover also minor bodies in the solar system have received the attention of the mission planners. Current manned space activity sees the ongoing projects on the International Space Station (ISS), suborbital flights and the planning of new missions to the Moon and Mars.

Many countries, like the United States, Russia, China, European Community, have the capability of putting spacecraft into orbit; satellites have now established a firm foothold as part of the infrastructure of society. There is every expectation that they have much more to offer in the future.

This Unit covers the fundamentals of spacecraft, the effects of space environments, mission analysis principles and different types of spacecraft subsystems. Topics include space debris, mission profile analysis, attitude control system design, applications for small satellites.

Since spacecraft systems are highly interdisciplinary, a systems perspective is encouraged to ensure that students are aware of how design decisions impact numerous features of the aerospace system.

More specifically, this Unit provides the student with a deep understanding of spacecraft subsystems, gives an overview of the different types of mission profiles, provides the knowledge to make a preliminary dimensioning of different subsystems.

In summary, the selected study topics cover the necessary theoretical background to determine the key parameters of spacecraft, evaluating design considerations and allowing to determine optimal subsystems selection.

Learning Outcomes

On completion of this unit the learner will be able to

1. *Discuss the fundamentals of spacecraft.*
2. *Describe the spacecraft environment and its effect on design.*
3. *Discuss mission analysis principles.*
4. *Describe different types of spacecraft subsystems.*

Unit: ETACT-706-2129- Thermal Control of Aerospace Vehicles

Unit level (MQF): 7

Credits : 6

Unit Description

Thermal control systems are an essential part of spacecraft design, ensuring that all parts of the spacecraft remain within acceptable temperature ranges at all times. This unit describes the fundamentals of thermal control design and reviews current thermal control technologies. The topics provide an overview of space missions and a description of the space environment, followed by coverage of the heat transfer processes relevant to the field. Moreover, thermal control technologies are described and thermal analysis reviewed.

The unit aims at providing an overview of systems tradeoff issues and of how the thermal design interacts with the overall system design and fits into the overall picture of spacecraft design.

More specifically, this Unit provides the student with a deep understanding of spacecraft configurations and thermal environments, gives an overview of the different types of thermal designs, provides the knowledge to make a preliminary thermal design analysis. It is assumed that the student has already a background in heat transfer and understands the fundamental principles of conductive, radiative, and convective heat transfer.

In summary, the selected study topics cover the necessary theoretical background to determine the key parameters for the thermal control of spacecraft, evaluating design considerations for the thermal modelling during the spacecraft project phases.

Learning Outcomes

On completion of this unit the learner will be able to

1. *Describe spacecraft systems and thermal environments overview.*
2. *Review of thermal design of spacecraft.*
3. *Discuss thermal control elements.*
4. *Discuss the thermal design analysis of spacecraft.*

Unit: ETACT-706-2130- Astrodynamics

Unit level (MQF): 7

Credits : 6

Unit Description

Astrodynamics, also called Orbital Mechanics, describes the motion of orbiting bodies like satellites and space vehicles that move under the influence of gravity.

This Unit covers the fundamentals of kinematics and dynamics of point masses and discusses advanced concepts in orbital mechanics. Topics include the two-body problem, preliminary orbit determination, interplanetary trajectories and rigid-body dynamics.

More specifically, this unit provides the student with a deep understanding of the orbital mechanics principles, gives an overview of different types of orbital manoeuvres, provides the knowledge to make calculations regarding the attitude dynamics of spacecraft.

In summary, the selected study topics provide the student with the necessary theoretical background to determine the position and velocity of orbiting bodies, using the fundamentals of elliptical orbits, allowing to determine optimal mission profiles solutions.

Learning Outcomes

On completion of this unit the learner will be able to

1. *Discuss the fundamentals of kinematics and dynamics of point masses.*
2. *Review orbital mechanics main principles.*
3. *Explain different types of orbital maneuvers.*
4. *Discuss the attitude dynamics of spacecraft.*