Indian Institute of Technology Jodhpur

Concept Note

for

Bachelors of Technology (B.Tech)

in

Aerospace Engineering

1 Introduction to Aerospace Engineering, Emerging Trends and Pertinence of the new academic unit

Aerospace engineering deals with the design, manufacturing, maintenance, and testing of aircraft and related systems. Aerospace engineering is distinguished by its integration of advanced concepts from aerodynamics, communications, satellite technology, navigation, and materials science to ensure the safe operation of aircraft and related systems. Over time, aerospace engineering has evolved beyond its traditional focus on aeromechanics to encompass a wide range of domains, including avionics, weather forecasting, satellite applications, space exploration, and many other emerging areas.

With India's continued expansion in space missions, defence modernisation, drone technologies, and autonomous systems, the demand for aerospace-relevant skills is increasing. India is the world's third-largest domestic aviation market, with a size of around USD 900 million. A 2022 report by NITI Aayog indicated an annual passenger growth of approximately 15% in the pre-COVID period, and this growth is expected to accelerate further with the expansion of the Indian economy. Also, over the last two decades, civil aviation travel has witnessed a substantial increase, and this trend is projected to continue. This rising demand is expected to lead to an expansion of the air fleet and increased manpower requirements in Maintenance, Repair, and Overhaul (MRO) services. Thus there is a need of trained aerospace engineering graduates to meet the growing demand in Indian aviation and space industry. With this context, the department of aerospace engineering at IIT-Jodhpur is proposing Bachelor of Technology (B.Tech) program in Aerospace Engineering. Admissions to this B.Tech program will be conducted through the Joint Seat Allocation Authority (JoSAA), in accordance with institute norms. An intake of 50 students is planned for the B.Tech program as per the norms of IIT-Jodhpur

Aerospace engineering unit worldwide consists of four thematic main subgroups that are (i) Aerodynamics and Fluid Mechanics, (ii) Structures and Materials, (iii) Propulsion and Combustion, and (iv) Guidance, Navigation, Control, and Autonomy. In addition to these four core subgroups, emerging areas such as Space and Astrodynamics, Cyber-physical systems, Avionics, Satellites, Space exploration, and Aerial Autonomous Systems are gaining prominence within aerospace engineering. Like other engineering disciplines, aerospace engineering continues to evolve with changing technological and societal needs. In the coming decades, sustainable aviation, hypersonics, reusable space access technologies, and autonomy and digitisation are expected to be key frontiers in the field. One of the most critical challenges of the present century is sustainable development, for which sustainable aviation is essential. New-age propulsion systems that include battery-powered, electric, hydrogen-based, and cryogenic systems require significant attention to reduce aviation emissions are important focus areas of research for sustainable aviation.

The present day world is moving towards industrialization of space. Technological advancements in hypersonic guidance and control, reusable launch vehicles, and interplanetary navigation are expected to play a pivotal role in space exploration and its subsequent industrialisation. Therefore advancements in propulsion technologies, such as nuclear and plasma propulsion are crucial. These developments will necessitate smarter approaches to structural health monitoring and the manufacturing of advanced aerospace materials. The integration of emerging technologies such as digital twins, artificial intelligence, and the Internet of Things (IoT) is another key area that has the potential to significantly impact aerospace engineering.

Drones with their civil and defence applications are also an important thrust area in aerospace engineering. Drones have evolved from their traditional defence-centric roles into a mainstream convergence of aerospace engineering and robotics. With the increasing use of drones in navigation and delivery, agriculture, search and rescue operations, climate monitoring, aerial photography, inspection, mapping and surveillance, the importance of counter-drone technologies is also expected to grow in the coming years.

2 Vision, Mission and Structure of the Academic Unit

Considering the emerging trends in Aerospace Engineering and societal needs stated in previous section, the department's vision is centred on integrating emerging technologies, such as digital twins, artificial intelligence, and related innovations. Such an approach will help produce highly skilled engineers, foster indigenous research, advance digital technologies, and strengthen India's leadership, all in alignment with the objectives of IIT Jodhpur and the National Education Mission. The aerospace engineering department's vision and mission are the following:

Vision

- Integrating aerospace engineering with new-age technologies, fostering multidisciplinary research for innovation, self-reliance and leadership in aerospace and allied technologies.

Mission

- Offer graduate, post-graduate and executive programs that emphasize on interdisciplinary approaches as per the requirements of the Indian aerospace industry.
- Develop a platform for product-oriented and multidisciplinary research involving governmental, industrial, and academic stakeholders.
- Facilitate the aerospace engineering research infrastructure as per the defence, civil and space-exploration national requirements.

The **objectives** of the B.Tech in Aerospace Engineering **program** at IIT-Jodhpur are formulated to align with the vision and mission and are as follows:

1. To provide foundational knowledge in fundamental principles of aerodynamics, propulsion, structural mechanics, flight mechanics and its control guidance, related to aerospace engineering.
2. Cultivate critical thinking by integrating theoretical knowledge with computational and experimental skills that are related to the design, analysis, and testing of aerospace vehicles and systems.
3. Expose students to hands-on experience on flying objects, emerging technologies, entrepreneurial opportunities, problem-solving capabilities of unmanned aerial systems design and related interdisciplinary prospects in aerospace engineering.
4. Showcase integration of the newer engineering concept in artificial intelligence and machine learning, internet of things, digital twin into aerospace engineering

The B.Tech program is designed to cultivate essential attributes in students to effectively support the program objectives. The following are the **attributes expected of graduates of the B.Tech in Aerospace Engineering**:

1. To have strong knowledge of fundamental subjects in aerospace engineering.
2. To have an understanding of various subsystems and their integration for several aerospace-related applications.
3. To have knowledge of current industrial practices in aerospace engineering.
4. Clarity on academic, administrative, industrial prospects and pathways in the aerospace engineering

The aerospace engineering department at Indian Institute of Technology Jodhpur adopts a matrix-based academic structure consisting of horizontals (core scientific disciplines) and verticals (application domains) to organize its academic activities. Horizontals represent the fundamental engineering knowledge areas that underpin aerospace technologies. Verticals correspond to industrial sectors and system-level applications where these principles are applied. The courses offered by the department are designed to build strong foundations in the horizontals, while enabling students to apply this knowledge to complex aerospace systems represented by the verticals. This matrix framework ensures that students develop both deep disciplinary expertise and system-level design capability. The vertical and horizontal structure of the department is as shown in figure 1.

3 Program Structure and Curriculum Progression

Table 1 presents the overall categorization and distribution of credits for the proposed B.Tech. program in Aerospace Engineering. The curriculum is systematically organized into Institute Core, programme core, open electives, and compulsory audit components to ensure a balanced and comprehensive educational structure. The Institute (I) core courses form the foundational component of the curriculum, comprising engineering, science, and humanities subjects. The Programme (P) core constitutes the major portion of the curriculum and is designed to develop discipline-specific knowledge in aerospace engineering. It includes Programme Compulsory (PC) courses that build fundamental and advanced concepts across the identified horizontal domains, Programme Electives (PE) that enable specialization aligned with vertical applications, and the B.Tech. Project (PP), which emphasizes independent problem-solving, design, and research. The Open Electives (O) provide flexibility to students to explore interdisciplinary areas beyond aerospace engineering, thereby promoting a broader academic perspective. In addition to graded components, the curriculum includes Compulsory Audit courses that have only satisfactory and unsatisfactory grades. The audit courses includes humanities, engineering practice, industry internships and designing assignments.

Table 2 presents the semester-wise distribution of credits across different course categories for the B.Tech. program in aerospace engineering. The title of the course for each semester is stated in table 3.[1] The structure reflects a systematic progression from foundational courses to specialization courses and projects. In the first two semesters, the curriculum is primarily composed of Institute (I) core courses, including Engineering (IE), Science (IS), and Humanities (IH). These courses establish the fundamental analytical, scientific, and communication skills required for engineering

[1] In table 2 and 3, the program compulsory and B.Tech project cells of the table are highlighted by yellow color, the elective courses (program and open) are highlighted in blue color and the compulsory Audit are highlighted with green color.

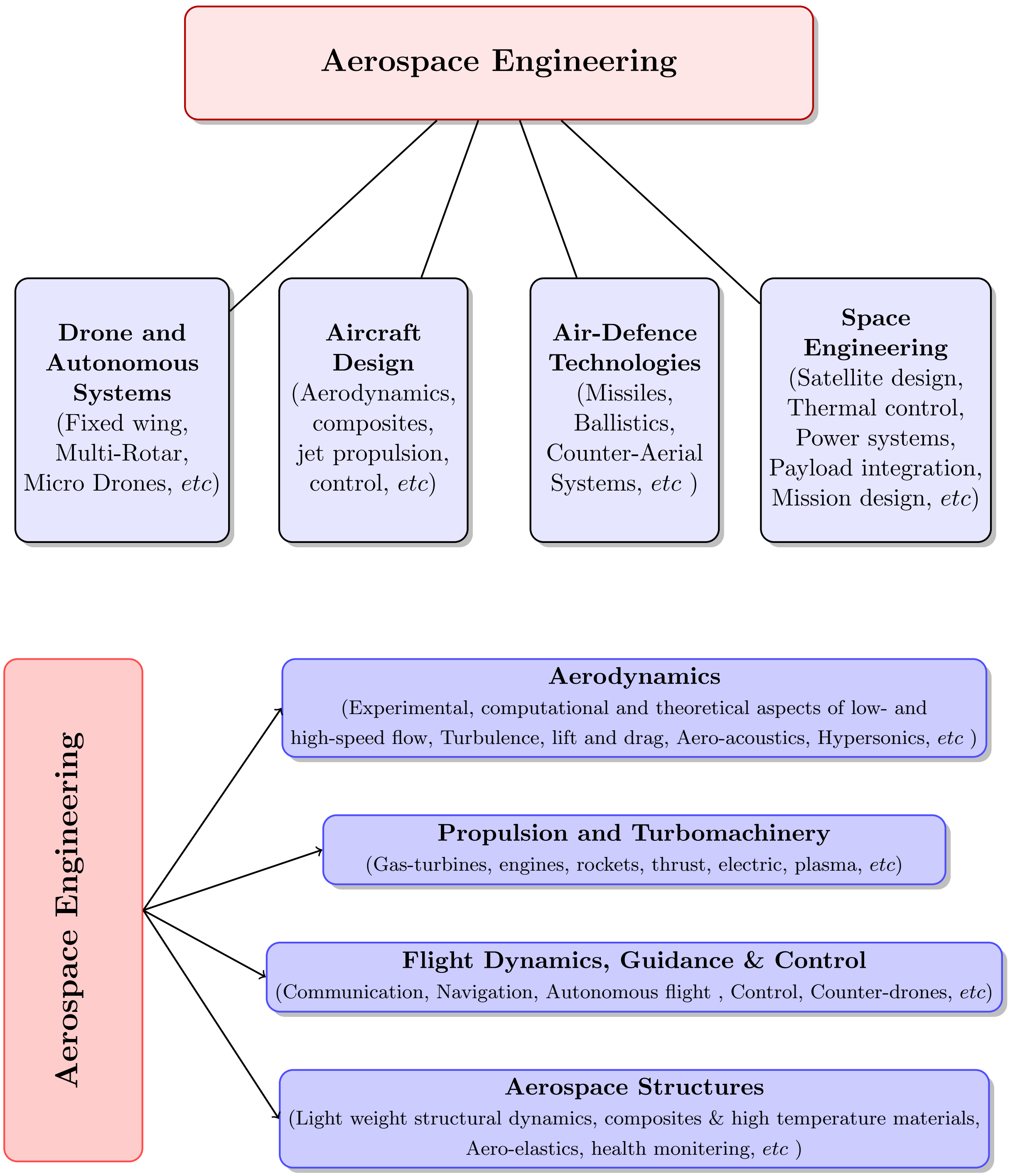

Figure 1: The vertical and horizontal structure of the aerospace engineering department are shown in top and bottom block diagram respectively.

Table 1: Course Categories and their distribution

S.N.	Course Type	Course Category	Credit	Total
1	Institute Core	Engineering (IE)	16	39 (27%)
		Science (IS)	17	
		Humanities (IH)	06	
2	Programme Core	Programme Compulsory (PC)	69	**93 (64.6%)**
		Programme Electives (PE)	18	
		B.Tech. Project (PP)	6	
3	Open (O)	Electives (OE)	12	12 (8.3%)
			Total (Graded)	**144 (100%)**
4	Compulsory Audit	Humanities (NH)	3	12
		Engineering (NE)	3	
		Industry-Academia Summer Internship outside IIT Jodhpur (two summers, minimum 45 days)	4	
		Design Credit	2	
Total for award of Degree (Graded + Non-Graded)				**156**

education. The credit load during this phase is carefully balanced to ensure a smooth transition from general engineering courses to aerospace engineering related courses.

From the third semester onwards, the emphasis shifts toward Programme Compulsory (PC) courses, which form the core of aerospace engineering education. These courses are distributed across multiple semesters to provide depth in key areas such as aerodynamics, propulsion, structures, and control. Programme Electives (PE) and Open Electives (OE) are introduced from fifth semester. The B.Tech. Project (PP) is positioned in the final year, allowing students to integrate knowledge acquired.

The course structure and title of the courses for the first, second, third and fourth semesters is as presented in table 3. In the initial two semesters primarily focus on building a strong foundation in engineering, basic sciences, and humanities, which are essential for the any engineering curriculum. The first semester emphasizes core engineering fundamentals such as Engineering Mechanics, basic programming through Introduction to Computer Science, and Mathematics, along with Physics and its laboratory component. The second semester continues this foundational approach with courses in Chemistry, Mathematics, and interdisciplinary subjects such as Bioengineering and Machine Learning. Practical exposure is further enhanced through laboratory work and engineering workshop practice. Design-oriented learning is continued through Engineering Design II. While humanities and professional orientation courses are included to align with institutional guidelines.

In the third semester, the courses introduce core engineering and aerospace fundamentals. that include Thermodynamics, Mechanics of Solids, and Mathematical Methods for Aerospace Engineers establish the essential analytical and physical principles. These are complemented by Low-Speed Aerodynamics along with Experimental Mechanics laboratory, which introduces students to experimental techniques in solid and fluid mechanics. In the fourth semester, students are exposed to High-Speed Aerodynamics, Heat and Mass transfer, Flight Mechanics and performance, Aerospace Materials and Structures and Signals and Systems, providing understanding of core aerospace top-

Table 2: Semester-wise distribution of credits

Category	**Total Credits**	**Semester**							
		I	II	III	IV	V	VI	VII	VIII
Engineering (IE)	**16**	8	5	3	-	-	-	-	-
Science (IS)	**17**	7	10	-	-	-	-	-	-
Humanities (IH)	**06**	3	3	-	-	-	-	-	-
Programme Compulsory (PC)	**69**	-	-	17	20	17	15	-	-
Program Electives (PE)	**18**	-	-	-	-	3	-	6	9
Open Electives (OE)	**12**	-	-	-	-		3	6	3
B.Tech. Project (PP)	**6**	-	-	-	-	-	-	3	3
Total credits	**144**	18	18	20	20	20	18	15	15
Humanities (NH)	**3**	2	-	-	-	1	-	-	-
Engineering (NE)	**3**	1	2	-	-	-	-	-	-
Summer Internship	**4**	-	-	-	-	-	-	-	-
Design Credit (ND)	**2**	-	-	-	-	-	-	-	-
Total credits	156	21	20	20	20	21	18	15	15

ics. The short summary of the topic included in the Program Compulsory courses without lab component are described in table 4.

The course structure and title of the courses for the fifth, sixth, seventh and eighth semesters is as presented in Table 3. The fifth semester focuses on strengthening core aerospace competencies with courses such as Flight Dynamics, Propulsion-I, Heat and Mass Transfer, and Aerospace Structural Dynamics. Design-oriented learning is introduced through Aircraft Component Design and Aerospace structural Dynamics. The Flight Dynamics and Avionics Lab introduces student the concepts of flight control and aerospace electronics. A program elective is also introduced in the fifth semester, The list of possible program electives courses and their relation with the structure of the academic unit is also described in table 5. In the sixth semester the Control of Mechanical Systems, Machine learning for Aerospace engineering, Aerospace System Engineering and Propulsion-II courses expose students to modern interdisciplinary approaches. Laboratory courses in Aircraft Design and Propulsion provide hands-on experience to students.

In the final year, the curriculum emphasises specialisation and independent learning. Students undertake a B.Tech Project, which fosters research, innovation, and problem-solving skills. A range of electives allows students to specialize in advanced areas such as aerodynamics, propulsion, structures, control systems, and computational methods as shown in table 5. For Minor in aerospace engineering, the courses stated in table 6 are required to be completed for students.

Table 4: Description of Program Compulsory Courses.

Course	**Description**
Thermodynamics	The Basic Thermodynamics course introduces the fundamental principles governing energy, heat, and work interactions in engineering systems. It covers the laws of thermodynamics, properties of pure substances, and analysis of closed and open systems. The course also includes thermodynamic cycles, entropy, and energy conversion processes relevant to engineering applications. Overall, it provides the foundational framework for analyzing and designing thermal and energy systems.
Mechanics of Solids	The Mechanics of Solids course develops fundamental understanding of stress, strain, and deformation in solid materials. It covers stress–strain relationships, elasticity, and analysis of structural members under axial, bending, torsional, and combined loading. The course also introduces energy methods and stability concepts such as buckling. Overall, it equips students with the analytical tools required for the design and analysis of engineering structures.
Mathematical Methods for Aerospace Engineers	This course introduces the fundamental concepts of multivariable calculus, linear algebra, complex analysis, and ordinary and partial differential equations, along with their engineering applications in aerospace and mechanical engineering. Numerical methods for solving ordinary differential equations, including Euler and Runge–Kutta methods, are also covered. In addition, the course includes foundational concepts of probability and introductory statistical methods relevant to mechanical and aerospace engineering.
Low-Speed Aerodynamics	This course will provides a comprehensive treatment of incompressible flow theory with a strong emphasis on aerodynamic applications. It introduces fundamental concepts such as potential flow, vortex dynamics, and panel methods for analyzing two-dimensional and three-dimensional lifting bodies. The text also covers airfoil and wing theory, including thin airfoil theory and related topic.
High-Speed Aerodynamics	This course provides a comprehensive introduction to high-speed (compressible) aerodynamics, covering fundamental concepts such as Mach number, wave propagation, and compressibility effects. It includes the analysis of isentropic and non-isentropic flows, shock waves, expansion fans, and flow behavior in nozzles and ducts. The course also addresses frictional and heat transfer effects in compressible flows, along with unsteady flow phenomena. Experimental techniques for measuring high-speed flows are introduced to connect theory with practical applications.
Introduction to Avionics	This course provides an overview of the electronic systems used in modern aircraft for communication, navigation, and control. It covers topics of sensors, data buses, flight control systems, and cockpit displays. The course also introduces of radar and communication systems. Overall, it equips students with a foundational understanding of integrated avionics systems and their role in ensuring safe and efficient aircraft operation.

Signals and Systems	This course is introduces the fundamental principles of signals and system analysis. The course will cover various basic tools of signal and system analysis such as signal classification, LTI systems, Properties of LTI Systems, Frequency Response, Laplace Transform, Z-Transform, Fourier Transform, Fourier Series, Discrete Time Fourier Transform (DTFT), Discrete Fourier Transform (DFT).
Aerospace Materials and Structural	This course introduces the fundamentals of stress, strain, and constitutive relations, followed by the governing equations of elasticity with applications to plane stress and plane strain problems. The course emphasizes the analysis of slender, thin-walled, and stiffened structures typical of aerospace systems, including beams and wing-box type configurations. Topics include bending of symmetric and unsymmetric sections, shear flow in open and closed thin-walled sections, shear center determination, and deflection analysis. Torsion of circular and noncircular members, including single- and multi-cell thin-walled sections, is treated in detail, along with combined bending–torsion, behavior under realistic loading conditions. The effects of temperature, material non-homogeneity, and modulus-weighted sectional properties are also considered. Structural stability through Euler buckling, as well as appropriate failure theories, are introduced to assess safety and performance. The course ultimately equips students with analytical and practical tools for modeling, analyzing, and designing efficient aerospace structural components. A general overview of measurement techniques and materials used in aerospace engineering will also be covered in this course. Processing techniques for aerospace materials and the criteria for material selection are also covered next. .
Flight Mechanics and Performance	This course focuses on the performance analysis of airplanes using fundamental principles of flight mechanics. It covers atmospheric models, drag polar estimation, and engine performance characteristics, along with detailed analysis of steady and accelerated flight, climb, range, and endurance. The course also includes aircraft manoeuvres, flight limitations, and take-off and landing performance. Overall, it equips students with the ability to evaluate and predict aircraft performance across different flight conditions
Dynamics & Control of Flights	This course focuses on the stability and control characteristics of airplanes, building on fundamental flight mechanics principles. It covers static and dynamic stability in longitudinal, lateral, and directional modes, along with control surface effectiveness and design considerations. The course also introduces stability derivatives, modes of motion, and aircraft response to disturbances. Overall, it equips students with the ability to analyze and design stable and controllable aircraft systems.

Aerospace Structural Dynamics	This course introduces the fundamental principles governing the dynamic behavior of aerospace structures. It begins with discrete systems, matrix formulation, and generalized equations of motion to analyze multi-degree-of-freedom systems and their response. The course examines free and forced vibration of undamped and damped systems, including special damping cases and gyroscopic effects. It then extends to continuous systems such as beams, membranes, and plates using variational and energy methods. Concepts of wave propagation and the finite element method are also introduced to analyze complex structural dynamics problems in aerospace engineering.
Propulsion I & II	The Propulsion I & II courses introduces the fundamental principles of aerospace propulsion, with emphasis on air-breathing engines in two courses. It covers thermodynamic cycle analysis, performance parameters such as thrust and efficiency, and the working principles of turbojet, turbofan, turboprop, and turboshaft engines. The course also includes introductory concepts of ramjet and scramjet propulsion. Overall, it provides a strong foundation for understanding propulsion system performance and energy conversion in aerospace applications. The detailed analysis and design of propulsion system components, particularly turbomachinery and combustion systems will also be covered in this course. It covers the working principles and performance of compressors and turbines, including stage dynamics, efficiency, and loss mechanisms. The course also addresses compressor–turbine matching, combustion processes, and afterburners in gas turbine engines. Overall, it equips students with the analytical and design skills required for advanced propulsion system development.
Heat and Mass Transfer	This course provides a comprehensive understanding of the three fundamental modes of heat transfer: conduction, convection, and radiation. It covers both theoretical foundations and practical applications, including steady and transient conduction, empirical correlations in convection, radiation exchange mechanisms and principles of mass transfer. The course also introduces heat exchanger analysis and design methodologies. Overall, it equips students with the analytical skills required to solve real-world thermal engineering problems.
Aircraft Component Design	The Aircraft Design course provides a comprehensive understanding of the aircraft design process, from mission requirements to preliminary configuration and sizing. It covers conceptual design, aerodynamic analysis, weight estimation, and performance evaluation, along with stability and control considerations. The course also introduces structural design principles, including load estimation and stress analysis of aircraft components. Overall, it equips students with the ability to integrate multidisciplinary aspects into a coherent aircraft design framework using modern computational tools.
Control of Mechanical Systems	The Control of Mechanical Systems course introduces the modeling, analysis, and control of dynamic systems using classical control theory. It covers system representation techniques, time and frequency response analysis, and stability concepts such as BIBO and Routh criteria. The course further includes controller design methods, including root locus and PID control, along with practical implementation aspects. Overall, it equips students with the skills to design and analyze control systems for real-world mechanical applications.

Machine Learning for Aerospace Engineering	This course is designed to empower students to harness data from diverse sources and integrate it with physics-based understanding to solve complex aerospace problems. The course will cover modern techniques such as machine learning, symbolic regression, reduced-order modeling, and hybrid physics-informed approaches, with applications spanning turbulence modeling, flow control, structural health monitoring, and digital twins. Emphasis will be placed on interpretability, generalization, and embedding physical constraints, ensuring that models are not just accurate but also trustworthy and deployable. By combining theory with hands-on projects using real experimental and CFD datasets, the course aims to prepare students to lead the next generation of aerospace innovation driven by data.
Aerospace Systems Engineering	The Aerospace Systems Engineering course provides a structured framework for the analysis, design, and integration of complex aerospace systems. It emphasizes requirement definition, system architecture development, and model-based systems engineering to support informed design decisions. The course also covers trade-off analysis, system integration, verification, and risk assessment across the system lifecycle. It enables students to develop multidisciplinary problem-solving skills aligned with industry practices in aerospace system design and development.

Table 3: Complete Semester-wise Curriculum Structure

Semester I						Semester II					
Cat	**Course**	**L-T-P**	**CH**	**NC**	**GC**	**Cat**	**Course**	**L-T-P**	**CH**	**NC**	**GC**
IE	Engineering Mechanics	3-0-0	3	-	3	IE	Introduction to Machine Learning	3-0-2	5	-	4
IE	Introduction to Computer Science	3-0-2	5	-	4	IS	Chemistry	3-0-0	3	-	3
IS	Physics	3-0-0	3	-	3	IS	Introduction to Bioengineering	2-0-2	4	-	3
IH	HSS I	3-0-0	3	-	3	IS	Chemistry Lab	0-0-2	2	-	1
IS	Physics Lab	0-0-2	2	-	1	IS	Mathematics II	2-1-0	3	-	3
IS	Mathematics I	2-1-0	3	-	3	IE	Engineering Workshop	0-0-2	1	-	1
IE	Engineering Drawing	0-0-2	2	-	1	IH	HSS II	3-0-0	3	-	3
NE	Engineering Design I	0-0-2	2	1	-	NE	Engineering Design II	0-0-2	2	1	-
NH	Communication Skill	0-0-2	2	1	-	NE	Introduction to Profession	0-0-2	2	1	-
NH	Social Connect and Responsibilities	0-0-1	1	0.5	-						
NH	Performing Arts / Sports	0-0-1	1	0.5	-						
	Total	**14-1-6**	**26**	**3**	**18**		**Total**	**13-1-8**	**24**	**2**	**18**
Semester III						**Semester IV**					
PC	Thermodynamics	3-1-0	4	-	4	PC	Heat and Mass Transfer	3-0-0	3	-	3
PC	Mechanics of Solids	3-1-0	4	-	4	PC	Signals and Systems	3-1-0	4	-	4
PC	Mathematical Methods for Aerospace Engineers	3-0-0	3	-	3	PC08	Aerospace Materials and Structures	3-1-0	4	-	4
PC	Low Speed Aerodynamics	3-1-0	4	-	4	PC	Flight Mechanics and Performance	3-0-0	3	-	3
PC	Experimental Mechanics Lab	0-0-4	4	-	2	PC	High Speed Aerodynamics	3-1-0	4	-	4
IE	Environment and Sustainability	3-0-0	3	-	3	PC	Aerodynamics and Aero-Structure Lab	0-0-4	4	-	2
	Total	**15-3-4**	**22**	-	**20**		**Total**	**15-3-4**	**22**	-	**20**
Summer Internship I (ND = 2 credits)											
Semester V						**Semester VI**					
PC	Dynamics & Control of Flights	3-0-0	3	-	3	PC	Propulsion-II	3-0-0	3	-	3
PC	Aerospace Structural Dynamics	3-0-0	3	-	3	PC	Control of Mechanical Systems	3-0-0	3	-	3
PC	Propulsion-I	3-0-0	3	-	3	PC	Machine Learning for Aerospace Engg.	3-1-0	4	-	4
PC	Introduction to Avionics	3-0-0	3	-	3	PC	Aerospace System Engineering	3-0-0	3	-	3
PC	Aircraft Component Design	3-0-0	3	-	3	OE	Open Elective	3-0-0	3	-	3
PE	Program Elective	3-0-0	3	-	3	PC	Aircraft Design and Propulsion Lab	0-0-4	4	-	2
PC	Flight Dynamics and Avionics Lab	0-0-4	4	-	2						
NH	Professional Ethics	1-0-0	-	1	-						
	Total	**18-0-4**	**22**	-	**20**		**Total**	**15-1-4**	**20**	-	**18**
Summer Internship II (ND = 2 credits)											
Semester VII						**Semester VIII**					
PP	Project	0-0-3	3	-	3	PP	Project	0-0-3	3	-	3
PE	Program Electives	6-0-0	6	-	6	PE	Program Electives	9-0-0	9	-	9
OE	Open Electives	6-0-0	6	-	6	OE	Open Electives	3-0-0	3	-	3
	Total	**12-0-3**	**15**	-	**15**		**Total**	**12-0-3**	**15**	-	**15**

Table 5: Block diagram for the list of elective courses. The courses highlighted in green and blue are the elective courses for undergraduate level and both undergraduate and post-graduate level respectively.

<table>
<tr><td>Aerodynamics
Boundary layer theory
Atmospheric Fluid Dynamics
Turbulent flows
Aero and Hydro-acoustics
Hypersonics Aerodynamics</td><td rowspan="2">ELECTIVE COURSES</td><td>Flight Dynamics, Guidance and Control:
Introduction of Mechatronics
Anti-Drone Technology
Dynamics of Space Systems
Estimation, Navigation & Guidance
Drone Technologies</td></tr>
<tr><td>Structure and Materials:
Mechanics of Composites
Basics of Finite Element Analysis
Fatigue and Fracture
Aeroelasticity
Structural Health Monitoring</td><td>Propulsion & Turbomachinery:
Optical Diagnostics Techniques
Fundamentals of Combustion
Propulsion System for UAV
Computational Fluid Dynamics and Heat Transfer
Atomization and Sprays</td></tr>
</table>

Table 6: List of Programme core courses for Minor in Aerospace Engineering

Cat	**Course**	**L-T-P**	**CH**	**NC**	**GC**
PC	Low Speed Aerodynamics	3-1-0	4	-	4
PC	Aerospace Materials and Structures	3-1-0	4	-	4
PC	High-speed Aerodynamics	3-1-0	4	-	4
PC	Dynamics & Control of Flights	3-0-0	3	-	3
PC	Propulsion-I	3-0-0	3	-	3
Total		**[15-3-0]**	**18**	-	**18**

Indian Institute of Technology Jodhpur

B.Tech. Aerospace Engineering
Curriculum and Course Contents
AY 2026-30

2nd year B.Tech. Aerospace Engineering
Curriculum Structure & Course Contents

IIIrd Semester

Title	**Mathematical Methods for Aerospace Engineers**	Number	MEL2XXX
Department Offered for	Department of Aerospace Engineering	L-T-P [C]	3-0-0 [3]
Prerequisite	Mathematics-I and Mathematics-II	Type	PC

Objective:

1. Equip students with an understanding of mathematical tools (vector calculus, linear algebra, complex analysis, differential equations) and their application in modelling and solving engineering systems
2. Introduce concepts of probability and statistics essential in analyzing and interpreting data.

Learning Outcomes: The students are expected to have the ability to:

1. Apply vector calculus, tensor analysis, matrix operations, probability and complex analysis concepts while addressing engineering problems involving multivariable systems,
2. To understand methods to solve ODEs and PDEs in contexts like vibrations and heat transfer problems.
3. To effectively use statistical and numerical methods to analyzing experimental data, conduct hypothesis testing, and solve engineering problems.

Contents:

1. **Vectors, Tensors and Linear Algebra [7 lectures]**: Gauss (divergence), Stokes and Green's theorems; Tensor notation and transformation. Matrix operations; LU factorization; Reduced row echelon form and rank; Independence, Basis & dimension; Orthogonality, projection and least square approximation; Determinant properties; Eigenvalues and Eigenvectors, Examples from Aerospace applications.
2. **Ordinary Differential equations (ODE's) [7 lectures]:** Second-order linear ODEs, System of ODEs, series solutions of ODEs; Laplace transforms; Fourier series, Fourier transform, Example of Mass-Spring System with Free and Forced vibration.
3. **Complex Analysis [7 lectures]:** Complex Numbers. Complex Plane, Analytic Function, Cauchy-Riemann Equations. Laplace's Equation, Exponential Function, Trigonometric and Hyperbolic Functions, Line Integral in the Complex Plane, Cauchy's Integral Theorem and Formula, conformal mappings and examples.
4. **Partial Differential Equations [6 lectures]:** Characterization of PDEs, Separation of Variables for Partial Differential Equations.
5. **Numerical Ordinary differential equations (NODE's) [4 lectures]:** Euler's Method, Runge-Kutta Method, Integrating Higher order ODE using system of ODEs, Boundary value problem using shooting method.
6. **Probability and Statistics [8 lectures]:** Probability and random variables, Central limit theorem and Probability distributions, distributions of several random variables, random sampling, point estimation and confidence intervals, Goodness of fit, regression, correlations

Textbook:

1. Kreyszig, E. (2011). Advanced engineering mathematics (10th ed.). John Wiley & Sons.

Reference Books:

1. Arfken, G. B., Weber, H. J., & Harris, F. E. (2011). Mathematical methods for physicists: a comprehensive guide. Academic press.
2. Strang, Gilbert. Introduction to Linear Algebra. 5th ed., Wellesley-Cambridge Press, 2016
3. Borisenko, A. I., and I. E. Tarapov. Vector and Tensor Analysis with Applications. Translated by Richard A. Silverman, Dover Publications, 1979.
4. Chapra, S. C., & Canale, R. P. (2021). Numerical methods for engineers (8th ed.). McGraw-Hill Education

Online Material for the Course:

1. Mathematical Methods in Engg. and Science, IIT Kanpur https://nptel.ac.in/courses/112104035
2. Advanced Engineering Mathematics, IIT Kharagpur https://nptel.ac.in/courses/111105167

Title	**Low Speed Aerodynamics**	Number	AEL2XXX
Department	Aerospace Engineering	L-T-P [C]	3~~-1~~ ~~0~~ [4]
Offered for	B. Tech. (AE);	Type	Core
Prerequisite	Nil		

Course Objectives

1. To introduce fundamental aerodynamic principles and flow theories.
2. To analyze lift generation, circulation theory, and aerodynamic forces acting on flying vehicles.
3. To evaluate and select suitable aerofoil designs and configurations for fixed-wing flying vehicles.

Learning Outcomes

1. Understand and apply fluid mechanics principles to aerial vehicle aerodynamics, including inviscid and viscous flow analysis.
2. Analyze aerofoil performance, lift generation mechanisms, and aerodynamic characteristics of aerial vehicle configurations.
3. Select appropriate aerofoils and aerodynamic designs for efficient aerial vehicle performance.

Contents:

1. **Introduction to Flight [4 Lectures]:** Evolution of aviation and space exploration; Categories of aircraft and launch/space systems; Roles and operational significance of the primary components of aircraft and space vehicles.
2. **Fluid statics [5 Lectures]:** Hydrostatics, Buoyancy, Stability of floating bodies, Rigid body motion.
3. **Governing equations for Inviscid fluid flow [5 Lectures]:** Control volume analysis for mass, momentum, and energy conservations, differential form of governing equations, Euler equation, and Bernoulli's equation.
4. **Potential Flow Theory [6 Lectures]:** Vorticity and Irrotational Flows, Velocity potential and stream function, Concepts of source, sink, doublet, vortex, and superposition principle; Complex potential concept.
5. **Viscous Flows and Boundary Layer Theory [7 Lectures]:** Stress and strain rate; Constitutive relations for Newtonian fluids; Navier-Stokes equation; Exact solution for pipe flows, Boundary layer equations; Blassius solution; Integral equations; Effect of pressure gradient.
6. **Basic Aerodynamic Concepts [5 Lectures]**: Definitions of lift, drag, pitching moment; Circulation and Kutta-Joukowski theorem, Kutta condition; Kelvin's circulation theorem, Biot-Savart Law, starting vortex and lift generation.
7. **Aerofoil Theories [7 Lectures]:** Thin Aerofoil Theory: Symmetric and cambered aerofoil, prediction of circulation; Lifting Line Theory: Induced drag; Element of lifting surface theory. Flow past swept and delta wings; Aerofoils for Fixed Wing Flights: e.g. Low-speed aerofoils; reflex aerofoils and their lift/drag characteristics.

Textbooks

1. Anderson, J.D. (2007), Fundamentals of Aerodynamics, McGraw-Hill
2. Frank M. White, and Henry Xue (2022), Fluid Mechanics, McGraw Hill

Reference Books:

1. John J. Bertin and Russell M. Cummings. (2021). Aerodynamics for Engineers, Cambridge University Press
2. Karamcheti K. (1980), Principles of Ideal-Fluid Aerodynamics, Krieger Pub Co

Online Material:

1. Fundamentals of Theoretical and Experimental Aerodynamics, IIT Kharagpur https://nptel.ac.in/courses/101105088

Title	**Experimental Mechanics Lab**	Number	AEL2xxx
Department	Aerospace Engineering	L-T-P [C]	0-0-4 [1]
Offered for	B. Tech. (AE);	Type	Core
Prerequisite	Nil		

PART A: Fluid Mechanics Lab

Course Objectives

1. To introduce students to experimental techniques and instrumentation used in fluid flow measurements.
2. To provide a practical understanding of fluid dynamics concepts such as Bernoulli's theorem, boundary-layer development, vortex motion, flow separation, and stall.
3. To develop the ability to analyse experimental data and correlate fluid dynamics measurements with theoretical fluid mechanics principles.

Learning Outcomes

1. Measure and analyse velocity, pressure, discharge, and force exerted by fluids using standard laboratory instruments and experimental methods.
2. Interpret flow behaviour, including boundary-layer growth, vortex flows, wake formation, and flow separation through experiments and visualisation techniques.
3. Apply fundamental principles of fluid mechanics to compare theoretical predictions with experimental observations and prepare technical reports.

Contents

1. Velocity measurement using Pitot-Static Probe and manometer measurements.
2. Measurement of metacentric height for floating bodies.
3. Measurement of free surface profiles in forced and free vortex motions and comparison with theoretical predictions.
4. Determination of discharge coefficient and flow rate using pressure difference measurements
5. Force exerted by an impinging jet on flat and curved plates
6. Study of radial flow patterns generated by source and sink configurations.
7. Determination of pressure coefficient distribution over a circular cylinder.
8. Measurement of laminar and turbulent boundary-layer thickness and velocity profiles.
9. Estimation of frictional head loss in circular pipes and friction factor.
10. Estimation of drag on bluff bodies from wake velocity deficit measurements.
11. Visualisation of stalled flow over an aerofoil/ flow separation in backward facing steps.

Textbooks:

1. Frank M. White, and Henry Xue, Fluid Mechanics, McGraw Hill.
2. John J. Bertin and Russell M. Cummings. (2021). Aerodynamics for Engineers, Cambridge University Press

Reference Books: Pijush K. Kundu, Ira M. Cohen, David R Dowling, Fluid Mechanics, Academic Press

Online Material: Introduction to Fluid Mechanics, IIT Kharagpur: https://nptel.ac.in/courses/112105269

PART B: Experimental Solid Mechanics Lab

Course Objective: To provide hands-on understanding of stress-strain behavior, deformation, and failure of materials through experimental methods

Learning Outcomes: The students are expected to have the ability to:

1. Experimentally determine the elastic and strength properties of materials.
2. Analyze structural response under axial, torsional, and bending loads.
3. Validate classical theories such as Euler_Bernoulli beam theory and column buckling.
4. Use strain measurement techniques for stress analysis.

Contents:

1. Uniaxial tensile test to determine elastic constants
2. Engineering stress-strain and true stress-strain.
3. Evaluation of Poisson's ratio on printed specimens.
4. Compression test of a 3D lattice.
5. Torsion test to determine elastic constants.
6. Characterization of fracture surface and verification of failure plane for brittle and ductile systems.
7. Beam bending test to verify the Euler-Bernoulli beam theory.
8. Stress measurement in a thin pressure vessel.
9. Beam bending to find deflection and stress.
10. Application of photoelasticity to measure stress concentration.
11. Buckling test.
12. Demo of DIC.

Text books

1. Bansal RK. A textbook of strength of materials:(in SI units). Laxmi Publications; 2010.
2. Bhavikatti SS. Strength of materials. Vikas Publishing House; 2002.

Reference books

1. Holzapfel GA. Nonlinear solid mechanics: a continuum approach for engineering John Wiley & Sons, Chichester. Q11. 2000.
2. Volokh K. Mechanics of soft materials. Singapore: Springer; 2016 Jan 1.
3. Haupt P. Continuum mechanics and theory of materials. Springer Science & Business Media; 2013 Apr 17.

Online course material

1. NPTEL-Introduction to Continuum Mechanics by A. Narayana Reddy, IIT Guwahati, https://nptel.ac.in/courses/112103167
2. Lectures on Continuum Physics by Dr. Garikipati, University of Michigan, https://open.umich.edu/find/open-educational-resources/engineering/lectures-continuum-physics

2nd year B.Tech. Aerospace Engineering
Curriculum Structure and Course Contents

IVth Semester

Title	**Aerospace Materials and Structures**	Number	AE2XXX
Department	Aerospace Engineering	L-T-P [C]	3-1-0 [4]
Offered for	B.Tech. (AE)	Type	Core
Prerequisite	None		

Learning objectives: The objectives of this course are to:

1. Develop a fundamental understanding of aerospace materials, their properties, processing methods, and performance in structural applications.
2. Analyze aerospace structures by understanding load paths, stress distribution, and structural behavior under different loading conditions.
3. Apply concepts of material selection, structural design, and failure analysis for safe and efficient aerospace systems.

Learning outcomes: After completing this course, students will be able to:

1. Evaluate the behavior and performance of aerospace materials based on mechanical properties, processing, and environmental effects.
2. Analyze aerospace structural components by applying load, stress, and deformation principles.
3. Assess structural integrity through design considerations, failure mechanisms, joints, and durability concepts.

Course Content:

1. **Introduction to aerospace materials & processing [7 Lectures]:** Overview of aerospace materials and properties, selection of materials, Processing of metals, alloys, and polymers, FRP composites, composites manufacturing, sandwich structures
2. **Material performance, failure and testing [8 Lectures]:** Mechanical testing of aerospace materials, failure theories, fracture mechanics and crack propagation, fatigue behavior, environmental degradation, brief of non-destructive testing (NDT)
3. **Aerospace structural concepts and configurations [8 Lectures]** : A brief history of aircraft and spacecraft structures, airframe components, stress-strain concept in structural components, torsion of thin wall structures with single and multiple cell, bending and shear forces, shear centre in thin-walled structures, skin-stringer idealisation of fuselage and wing structures,
4. **Loads, stress analysis and aerospace structural performance [8 Lectures]:** Energy methods, aircraft and spacecraft loads and load transfer mechanisms, torsional loading of fuselage, bending of wing structures, buckling of column and plates, selection of design criteria.
5. **Aerospace structural design, failure and joints [8 Lectures]**: Design philosophy and approach, safety, regulations, and standard certification requirements, design for fatigue and crack growth, structural joints, durability and lifecycle considerations, AI/ML applications for structural design.

Textbooks:

1. Mouritz AP. Introduction to aerospace materials. Elsevier; 2012 May 23.
2. Megson TH. Aircraft structures for engineering students. Elsevier; 2012 Feb 20.

Reference book:

1. Alderliesten R. Introduction to aerospace structures and materials. TU Delft OPEN Publishing; 2018 Dec 12.

Online materials:

1. NPTEL: Aerospace Structural Analysis by Prof. Mira Mitra, IIT Kharagpur, https://nptel.ac.in/courses/101105332
2. DelftX: Introduction to Aerospace Structures and Materials by Jos Sinke, Tu Delft, https://www.edx.org/learn/aeronautical-engineering/delft-university-of-technology-introduction-to-aerospace-structures-and-materials

Title	**Flight Mechanics and Performance**	Number	AE3xx
Department	Aerospace Engineering	L-T-P [C]	3-~~0~~ ~~0~~ [3]
Offered for	B. Tech. (AE, ME);	Type	Core
Prerequisite	None		

Course Objectives

1. To develop a strong understanding of the fundamental principles governing aircraft flight mechanics, aerodynamics, and performance.
2. To analyze aircraft motion, stability, control, and maneuvering characteristics under various flight conditions.
3. To apply theoretical and computational methods for evaluating aircraft performance parameters such as takeoff, landing, climb, range, endurance, and flight stability.

Learning Outcomes: The students are expected to have the ability to:

1. Calculate and evaluate key aircraft performance metrics including lift, drag, thrust requirements, climb performance, range, and endurance.
2. Analyze static and dynamic stability characteristics of aircraft and explain the influence of control surfaces and aerodynamic design parameters.
3. Apply flight mechanics principles and equations of motion to solve practical aerospace engineering problems using analytical or simulation tools.

Contents:

1. **Introduction [5 Lectures]:** Aircraft types, Atmosphere properties, basics aerodynamic parameters
2. **Aircraft Geometry and Aerodynamic forces [10 Lectures]:** Aircraft geometry and coordinates systems, Aerodynamic coefficients, Dynamic pressure, non-dimensional parameter. Lift generation, lift curve, Drag Components (parasite, induced and wave drag), drag polar, minimum drag condition, High lift devices (flaps, slats, leading-edge devices), lift augmentation and effect on take-off and landing.
3. **Equations of Motions [5 Lectures]:** Fundamentals of aircraft motions, Aircraft equations of motion, Steady flight level, Climbing and descending flight
4. **Aircraft performance [11 Lectures]:** Performance of Take-off(Ground roll, Rotation and lift-off, balanced field length), Landing(Approach and flare, landing distance, Braking effect, reverse thrust), Turning flight and maneuvering, Performance envelops (flight envelope , v-n diagram, stall boundaries, operational limit), range and endurance(Breguet range equation, Fuel consumption, Jet aircraft range, Propeller aircraft endurance, Payload-range tradeoff)
5. **Supersonic flight basics [8 Lectures]:** Compressibility effects, Shock waves, Critical Mach number, Area rule, Supersonic drag rise.

Textbooks

1. John D. Anderson — Introduction to Flight, McGraw Hill, 3rd Edition (1989), ISBN 0-07-001641-0
2. McCormick — Aerodynamics Aeronautics and Flight Mechanics, 6th Edition(2010), Wiley,ISBN-13: 9780471575061

Reference Books

1. Perkins & Hage — Airplane Performance Stability and Control , 1st Edition reprint(1991), ISBN-13**:** 9780471680468

Online Course Material: https://www.coursera.org/learn/basis-flight-mechanics

Title	**High Speed Aerodynamics**	Number	AExxx
Department	Aerospace Engineering	L-T-P [C]	3-1 0 [4]
Offered for	B. Tech. (AE, ME);	Type	Core
Prerequisite	Low-speed Aerodynamics/Fluid Mechanics		

Course Objectives

1. Provide a foundational exposure to high-speed aerodynamics, highlighting physical phenomena arising in compressible flows such as density variation, wave propagation, and compressibility effects.
2. Build analytical understanding of flow features unique to supersonic regimes, including shock formation, expansion processes, and their influence on aerodynamic performance.
3. Familiarize students with practical high-speed flow applications and introduce basic experimental and visualization approaches used in supersonic wind tunnel studies.

Learning Outcomes: The students are expected to have the ability to:

1. Estimate flow properties in high-speed regimes using appropriate compressible flow relations and simplified models.
2. Interpret fundamental flow features such as shock waves and expansion fans in canonical configurations (e.g., wedges, nozzles, and airfoils).
3. Relate high-speed flow concepts to engineering systems such as aircraft, propulsion devices, and external aerodynamic configurations.

Contents

1. **Introduction [4 Lectures]:** Review of thermodynamics; Definition of Compressible flows, Conservation equations for Inviscid flows.
2. **Isentropic Flows [6 Lectures]:** Speed of sound and Mach number, Wave propagation, Static and stagnation conditions, isentropic flows with area change, isentropic nozzle operation; Prandtl-Meyer expansion flows: Prandtl-Meyer function.
3. **Non-Isentropic Flows-Normal and Oblique Shock Theory [7 Lectures]:** Normal shock relations, Rankine-Hugoniot equations.; 2-D flow equations, Oblique shock relations, Oblique shock chart, Shock reflections, Regular reflections and Mach reflections, Shock Polar, Conical shock flows
4. **Adiabatic flow with area change [5 Lectures]:** Normal shock in c-d nozzles, oblique shocks in overexpanded and under expanded nozzle flows.
5. **Compressible flow with friction (Fanno Flow)/ Heat Transfer (Rayleigh flow) [7 lectures]:** Fanno Flow: Working equations, Fanno line and friction choking, Correlations with shock; Rayleigh flow: Working equations, Rayleigh line and Thermal choking, Correlations with shock wave.
6. **Unsteady compressible flows [4 Lectures]: 1**-D wave motion: simple and finite waves, Riemann invariants, wave propagation in shock tube, Moving-shock relations, blast waves;
7. **High-Speed Aerodynamics and Measurements in Compressible Flows [6 Lectures]**: Prandtl-Glauert rule, Aerodynamic design for High Speeds Critical Mach Number, Supercritical Aerofoils, Swept Wings, Area Rule, Shock Expansion Theory for diamond shaped airfoils; Pressure and Mach number measurements, Schlieren and shadowgraph, supersonic wind tunnel operations, Hypersonic shock tunnels.

Textbooks

1. Zucker R. D. and Biblarz O., Fundamentals of Gas Dynamics, Wiley
2. John. D. Anderson, Modern Compressible flow with Historical Perspective, McGraw-Hill

Reference Book: John J. E. A. and Keith T., Gas Dynamics, Prentice Hall

Online Course Material: https://nptel.ac.in/courses/101108086

Title	**Aerodynamics and Aero-Structure Lab**	Number	AExxx
Department	Aerospace Engineering	L-T-P [C]	0-0-4 [2]
Offered for	B. Tech. (AE, ME);	Type	Core
Prerequisite	Basic Fluid Mechanics		

PART A: Aerodynamics Lab

Course Objectives: To develop the ability to relate theoretical flow concepts in low-speed and high-speed aerodynamics with experimentally observed flow features in internal and external flows.

1. To train students with lift and drag measurements in airfoils.
2. To train students in high-speed flow diagnostics, including pressure-based measurements and optical visualization techniques.
3. To introduce students to steady and unsteady shock phenomena and their relevance in practical aerodynamic and propulsion systems.

Learning Outcomes: The students are expected to have the ability to:

1. Identify and interpret key flow features such as, lift coefficient, drag coefficient, choking, shock waves, expansion fans, and jet structures from experimental observations.
2. Measure and compute flow properties (Mach number, pressure ratios, mass flow rate) using standard diagnostic techniques in compressible flows.
3. Correlate experimental data with theoretical predictions for isentropic flows, normal/oblique shocks, and nozzle flow behavior.

Laboratory Experiments

1. Measurement of surface pressure coefficients over an aerofoil and estimation of lift characteristics.
2. Measurement of aerodynamic coefficients using a force balance system
3. Prediction of choking point and mass flux variation in a convergent nozzle with a change in back pressure.
4. Mach number prediction in supersonic flow using Pitot tube pressure measurement.
5. Schlieren and Shadowgraph optical flow visualization techniques for shock wave visualization.
6. Evaluating convergent-divergent (c-d) nozzle flow pressure curve and finding critical pressure ratios.
7. Prediction of normal shock location in c-d nozzle for various pressure ratios.
8. Oblique shock wave angle prediction with variation in flow deflection angle.
9. Prandtl-Meyer Expansion Fan Study
10. Over and under expanded nozzle jets and flow property evaluation across the first shock diamond.
11. Transition criteria for regular reflection to Mach reflection in wedge-induced shock reflections.
12. Mach number prediction of moving shock in shock tubes using pressure measurements.

Textbooks

1. Anderson, J.D. (2007), Fundamentals of Aerodynamics, McGraw-Hill
2. Zucker R. D. and Biblarz O., Fundamentals of Gas Dynamics, Wiley

Reference Book: John J. E. A. and Keith T., Gas Dynamics, Prentice Hall

PART B: Aero-Structure Lab

Learning objectives: The objectives of this course are to:
1. Develop practical understanding of aerospace materials, their mechanical behavior, testing methods, and structural applications requirements through laboratory experiments.
2. Perform experimental analysis of aerospace structural elements under different loading conditions.
3. Apply experimental and computational techniques to evaluate structural integrity, material performance, and failure mechanisms in aerospace components.

Learning outcomes: After completing this course, students will be able to:
1. Conduct structural experiments on aerospace materials and interpret the obtained results.
2. Analyze the behavior of aerospace structural members subjected to static and dynamic loading conditions.
3. Evaluate failure mechanisms, deformation characteristics, vibration response, and structural performance of aerospace systems using experimental and computational tools.

Laboratory classes :
1. Rockwell/Brinell hardness measurement of aerospace materials
2. Beam bending test to verify the Euler-Bernoulli beam theory.
3. Fabrication of composite laminate and sample preparations
4. Load measurement in different members of a truss system
5. Verification of Maxwell's reciprocal theorem
6. Torsional test of thin-walled structures
7. Shear center determination of thin-walled sections
8. Buckling analysis of columns and plates
9. Structural Joints and failure analysis of bolted/Riveted connections
10. Free and forced vibration of SDOF/MDOF systems
11. Modal analysis and frequency measurement of cantilever beams

Text books:
1. Mouritz AP. Introduction to aerospace materials. Elsevier; 2012 May 23.
2. Megson TH. Aircraft structures for engineering students. Elsevier; 2012 Feb 20.

Reference book:
1. Alderliesten R. Introduction to aerospace structures and materials. TU Delft OPEN Publishing; 2018 Dec 12.

Online materials:
1. NPTEL: Aerospace Structural Analysis by Prof. Mira Mitra, IIT Kharagpur, https://nptel.ac.in/courses/101105332
2. DelftX: Introduction to Aerospace Structures and Materials by Jos Sinke, Tu Delft, https://www.edx.org/learn/aeronautical-engineering/delft-university-of-technology-introduction-to-aerospace-structures-and-materials
3. Virtual labs: Basic Structural Analysis, https://bsa-iiith.vlabs.ac.in/List%20of%20experiments.html

3rd year B.Tech. Aerospace Engineering
Curriculum Structure & Course Contents

Vth Semester

Title	**Dynamics & Control of Flight**	Number	AExxx
Department	Aerospace Engineering	L-T-P [C]	3-0 0 [3]
Offered for	B. Tech. (AE, ME);	Type	Core
Prerequisite			

Course Objectives

1. Build a solid foundation in aircraft flight dynamic stability by understanding forces, moments and the governing equations of motions for fixed-wing aircraft.
2. To understand how different control surfaces influence the flight behavior
3. Use analytical relations to define controls of flight

Learning Outcomes

The students are expected to have the ability to:

1. Understand flying performances while climbing, descending or maintaining flight level
2. estimate stability of the aircraft and factors which can destabilise the aircraft.
3. design a controller for steady flight level and autopiloting for a given flight path in navigation route.

Contents

1. **Introduction [5 Lectures]:** Body, wind and inertial frames, Axes and sign conventions, Lift, drag, thrust, weight, aerodynamic coefficient, External Forces and Moments, Free body diagram.
2. **Static Stability [11 Lectures]:**, Concept of Stability, Trim condition and trim stability analysis, Longitudinal Static Stability, Static margin, Lateral Stability, Directional Stability, Control Surfaces.
3. **Dynamic Stability [8 Lectures]:**. Linearization approximations for small disturbance, Longitudinal Stability, Short Period mode, Phugoid mode, Lateral Directional Dynamics, Dutch-Roll Mode, Roll mode and spiral mode, Eigen value analysis
4. **Flight Control System [11 Lectures]:**. Introduction to flight control, manual vs automatic control, Control effectiveness, Stability augmented systems, Autopilot basics, flight path control navigation route, Fly-by-wire systems
5. **Applications [4 lectures]:** Matlab/Simulink Models for flight control simulation, Non-linear Flight dynamics

Textbooks

1. Michael V. Cook, Flight Dynamics Principles: A Linear Systems Approach to Aircraft Stability and Control, Butterworth-Heinemann / Elsevier, Edition: Third (2013)
2. Brian L. Stevens, Frank L. Lewis, Aircraft Control and Simulation

Reference Books

1. Bernard Etkin, Dynamics of Atmospheric Flight.1972 (Wiley)

Online Course Material

1. Flight dynamics I - Airplane performance, IIT Madras https://nptel.ac.in/courses/101106041

2. Flight dynamics II - Airplane stability and control, IIT Madras https://nptel.ac.in/courses/101106043

Title	**Aerospace Structural Dynamics**	Number	AE3xxx
Department	Aerospace Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech (AE)	Type	Core
Prerequisite	None		

Learning Objectives:

The objectives of this course are to:

1. To introduce the fundamentals of structural dynamics and vibration behavior in aircraft structures.
2. To develop analytical and numerical skills for solving multi-degree-of-freedom vibration problems.
3. To understand modal analysis, continuous system vibrations, and numerical methods used in aerospace structural dynamics.

Learning outcomes:

After completing this course, students will be able to:

1. Analyze free and forced vibration behavior of aircraft structural systems under dynamic loading.
2. Apply modal and numerical techniques for multi-degree-of-freedom and continuous systems.
3. Evaluate dynamic response characteristics of aerospace structures using analytical and numerical methods.

Course Content:

1. **Introduction to aircraft structural dynamics [5 Lectures] :** Introduction to structural dynamics and aerospace applications, degrees of freedom and system, dynamic loads, fundamentals of vibration measurement.
2. **Single degree-of-freedom (SDOF) systems [5 Lectures] :** Undamped free vibration, equation of motion, damped vibration, forced vibration, resonance and transmissibility, effect of vibrating support/base excitation.
3. **Response to dynamic loading [6 Lectures]:** Dynamic loading concepts, impulsive and periodic loading, Duhamel's integral formulation, Laplace transform methods, numerical methods.
4. **Multi-degree-of-freedom (MDOF) systems [8 Lectures] :** Equations of motion, free vibrations, orthogonality principle, forced vibrations, modal coordinates and modal transformation.
5. **Modal analysis and continuous systems [8 Lectures] :** Modal response analysis, longitudinal vibration of rods, torsional vibration of shafts and rods, vibrations of strings and beams, Euler-Bernoulli beam equation, applications to aircraft wings and fuselage structures.
6. **Approximate and computational methods in structural dynamics [7 Lectures] :** Rayleigh method, Rayleigh–Ritz method, Galerkin's method, finite element concepts, computational approaches.

Text books:

1. Aeroelasticity FE. Introduction to Structural Dynamics and Aeroelasticity by G. Alvin Pierce, Dewey H. Hodges, Cambridge Aerospace Series, 2002.
2. Donaldson BK. Introduction to structural dynamics. Cambridge University Press; 2006 Oct 23.

Reference books:

1. Thomson W. Theory of vibration with applications. CrC Press; 2018 Feb 6.
2. Craig Jr RR, Benzley SE. Structural dynamics, an introduction to computer methods, John Wiley & Son, 1982.
   Mario P, Young HK. Structural dynamics: Theory and computation, CBS Publishers & Distributors,

2019.

Online materials:

1. NPTEL: Aircraft Structural Dynamics by Dr. D.K. Maiti, Dr. Anup Ghosh, IIT Kharagpur, https://nptel.ac.in/courses/101105022

Title	**Propulsion-I**	Number	AExxxx
Department	Aerospace Engineering	L-T-P [C]	3–0–0 [3]
Offered for	B. Tech. (AE, ME)	Type	Core
Prerequisite	Thermodynamics		

Course Objectives

1. Introduce gas turbine propulsion concept – cycle and its components
2. Introduce different types of gas turbine engines
3. Familiarize them with application of conservation laws and analytical methods to perform both cycle analysis and component analysis under ideal and non-ideal conditions
4. Provide them with a justification of typical flow values and design parameters

Learning Outcomes

1. Have a basic understanding of gas turbines, their sub-variants, and understand how to select them based on the requirements
2. Identify the design constraints and perform a quick first-cut design or analysis of gas turbines and their components
3. Apply simple conservation principles to gain fast and deep insights into the behaviour of different propulsion systems

Contents

1. **Introduction and Review of Fundamentals [7 lectures]:** History of gas turbine engine development introduction to gas turbines and their different types, review of conservation laws, one-dimensional flow of gases
2. **Classification of gas turbines and Engine Performance [9 lectures] –** turboprop engines, turbojet engines, turbofan engines, turboshaft engines**,** Thrust equation, take-off thrust, specific thrust, specific fuel consumption, thermal efficiency, propulsive efficiency, overall efficiency**,** ideal Brayton cycle analysis, real cycle analysis, thermal efficiency and parametric evaluation
3. **Propellers, inlets ducts and exhaust nozzles [7 lectures] -** propeller terminology, actuator disc theory, blade-element theory, strength of propellers, flight Mach number and its impact on inlet duct design, ideal and real diffusers, subsonic and supersonic inlets, exhaust nozzle, adiabatic efficiencies of inlets ducts and exhaust nozzles, effect of boundary layers formation
4. **Combustors and afterburners [5 lectures] –** chemical reactions, flame temperature, chemical kinetics, combustion chamber design and combustion instability, afterburner operations,
5. **Turbomachinery and component matching [11 lectures] –** Euler's turbomachinery equations, rotor and stator frame of references, angular momentum, work and compression, multi-stage axial compressor, compressor instability – stall and surge, centrifugal compressors, radial diffusers, turbine performance, turbine blade cooling, turbine blade losses, engine component matching and off-design analysis

Textbooks:

1. Saeed Farokhi, "Aircraft Propulsion", Wiley 2^{nd} edition
2. Philip Hill and Carl Peterson, "Mechanics and Thermodynamics of Propulsion", Pearson, 2^{nd} Edition

References:

3. Jack D. Mattingly, "Elements of Propulsion: Gas Turbines and Rockets", AIAA Education Series

Online Material:

Title	**Introduction to Avionics**	Number	AExxx
Department	Aerospace Engineering	L-T-P [C]	3-0 0 [3]
Offered for	B. Tech. (AE, ME);	Type	Core
Prerequisite	None		

Course Objectives

1. To understand the fundamentals of avionics systems.
2. To explain aircraft electrical, communication, navigation, and surveillance systems.
3. Understand cockpit instrumentation and display technologies.
4. To understand avionics used in spacecraft and satellites

Learning Outcomes

The students are expected to have the ability to:

1. Describe flight control instruments and communication systems.
2. Understand radar, satellite navigation, and modern digital avionics.
3. Gain introductory exposure to avionics integration, safety, and operations.

Contents

1. **Introduction [3 Lectures]:** Aerospace avionics, aircraft and satellite subsystems, Reliability, safety and Environmental constraints.
2. **Aircraft Electrical systems [5 Lectures]:** Aircraft Electrical power system, Power distribution and Protection, Battery and emergency power, Auxiliary Power Unit (APU), Emergency electrical systems operated on APU, Aircraft wiring standards, Shielding and grounding EMI/EMC issues.
3. **Aircraft instruments and display [5 Lectures]:** Altimeter, Air speed indicator, Vertical speed indicator, Gyroscopic instruments (attitude indicator, heading indicator, turn coordinator), Engine monitoring and warning instruments, fuel systems and indications, Modern displays (Primary flight display (PFD), MFD, HUD, HMD)
4. **Aircraft Communication systems [4 Lectures]:** Communication principles, frequency bands, modulation basics, VHF radios, HF communications, Data Communication systems, Satellite communication for planes.
5. **Navigation systems [5 Lectures]:** Dead reckoning, Radio Navigation, Coordinates systems, radio navigation aid (NDB, ADF, VOR systems) Distance measuring instruments (DME operations and TACAN overview), Instrumentation landing systems (ILS) Localizer, Glide slope, Marker Beakons,
6. **Surveillance and Radar Systems [4 lectures]:** Fundamental of Radar, Radar equations, Pulse radar, Doppler radar, Airborne Weather radar, Secondary Surveillance radar and Transponder, Collision avoidance System, TCAS, Electronic warfare basics, Radar warning receiver and jamming concept
7. **Space Avionics [5 lectures]:** Satellites, Space Probes, Launch Vehicles, Crewed spacecraft, Environment constraints, Spacecraft Electrical Systems (Solar panel and photovoltaic systems). Spacecraft communication systems. Spacecraft Communication systems. Uplink and downlink systems, telemetry, deep space communication basics
8. **Spacecraft Navigation and guidance systems [8 lectures]:** Orbit Determination, attitude determination method, star trackers, Sun sensors, GPS/GNSS for Spacecrafts. Attitude determination and control system, Spacecraft orientation control, Reaction wheel, Control moment gyroscopes, Magnetorquers, Thruster based controllers.

Textbooks

1. R. P. G. Collinson , Introduction to Avionics Systems, 3rd edition, 2011
2. Albert D. Helfrick , Principles of Avionics, 9th edition, 2018

Reference Books

1. R.P.G. Collinson , Digital Avionics Systems.1989 (Springer), 3rd edition. 2011

Title	**Aircraft Components Design**	Number	AExxxx
Department	Aerospace Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech (AE)	Type	Core
Prerequisite	None		

Objectives: The objective of this course is to provide students with a comprehensive understanding of the aircraft design process, starting from mission requirements to preliminary structural sizing. The course aims to develop the ability to perform conceptual design, including configuration selection, weight estimation, aerodynamic analysis, and performance evaluation. It further introduces students to stability considerations, load estimation, and airworthiness requirements.

Learning Outcomes: The student will have ability to-
1. Interpret mission requirements and develop preliminary aircraft configurations.
2. Perform weight estimation, aerodynamic design, and aircraft performance analysis.
3. Design major aircraft components, including wing, fuselage, and tail surfaces.

Contents-

1. **Introduction & Conceptual Aircraft Design [9 Lectures]:** Overview of aircraft design process and design philosophy. Conceptual design based on mission requirements. Survey of existing aircraft configurations (transport, fighter, UAV, etc.). Lofting and preliminary layout sketches. Initial sizing and design constraints. Preliminary weight estimation methods (statistical and empirical). Introduction to design trade-offs and optimization.
2. **Aerodynamic Design & Performance Analysis [10 Lectures]**: Selection of wing loading and thrust-to-weight ratio. Wing section selection and planform design. Estimation of aerodynamic characteristics (lift, drag, moment). Performance analysis: range, endurance, climb, take-off, and landing. Fuselage layout and weight balance considerations. Tail design: horizontal and vertical tail sizing. Control surfaces: ailerons, elevators, rudders.
3. **Load Estimation & Structural Design Fundamentals [10 Lectures]:** Estimation of spanwise load distribution (wing and tail). Introduction to structural design philosophy. V-n (V-g) diagram and maneuver/gust loads. Airworthiness requirements and certification basics. Stress resultants in swept and unswept wings. Application of modified beam theory in wing analysis.
4. **Structural Sizing & Advanced Analysis [10 Lectures]:** Methods for wing stress analysis. Yielding-based structural design. Buckling (of columns, panels, and stiffened panels) based design of thin structures. Rib spacing and wing box design. Preliminary structural layout and sizing of wing components. Margin of safety and design checks. advanced analysis (using FEM based commercial/open-source software) for full wing.

Text books:

1. Megson TH. Aircraft structures for engineering students. Elsevier; 2012 Feb 20.
2. Bruhn EF. Analysis and design of airplane structures, 1949 Jan.

Reference books:

1. Raymer D. Aircraft design: a conceptual approach. American Institute of Aeronautics and Astronautics, Inc.; 2012 Aug 1.
2. Sadraey MH. Aircraft design: A systems engineering approach. John Wiley & Sons; 2024 Oct 15.
3. Kundu AK. Aircraft design. Cambridge University Press; 2010 Apr 12.

Online materials: NPTEL: Introduction to Aircraft Design by Prof. A.K. Ghosh, IIT Kanpur, https://onlinecourses.nptel.ac.in/e-learning/preview/noc21_ae04

Title	**Flight Dynamics and Avionics lab**	Number	AExxx
Department	Aerospace Engineering	L-T-P [C]	0-0 4 [2]
Offered for	B. Tech. (AE, ME);	Type	Core
Prerequisite	Dynamics and control of Flight and Avionics (enrolled or completed)		

PART A: Flight Dynamics and Control Lab

Course Objectives

1. To introduce students to the fundamental principles of aircraft flight dynamics and control systems.
2. To provide practical exposure to stability, controllability, and aircraft response analysis.
3. To enhance understanding of aircraft performance through hardware-based experiments.

Learning Outcomes

The students are expected to have the ability to:

1. Explain the fundamentals of aircraft stability and control.
2. Analyze longitudinal and lateral-directional flight dynamics of aircraft.
3. Model aircraft motion using transfer functions and state-space methods.
4. Evaluate aircraft response characteristics such as damping ratio, natural frequency, and stability margins.
5. Design and test basic feedback controllers for aircraft applications.

Contents

1. Introduction to control surfaces on the aircraft
2. Static Longitudinal stability analysis
3. Maintaining trim stability
4. Static Lateral and Directional Stability analysis
5. Lateral Dynamic modes-Dutch roll, Spiral and Roll mode
6. Aircraft pitch control using PID
7. Roll attitude control in aircraft using feedback system
8. PID tuning in Quadcopter motions for hover control
9. Autopilot architecture in Quadcopter
10. Manual flight of quadcopter
11. Tracking autonomous flight path with GPS
12. Tracking flight path with IMU sensor

PART B: Avionics LAB:

Course Objectives

1. To Provide hands-on experience of subsystems of aircraft assembly and instruments
2. To familiarise students with modern avionics architectures
3. To develop practical skills to operate avionics instruments

Learning Outcomes

The students are expected to have the ability to:

1. Analyze basic aircraft electrical and avionics systems.
2. Perform calibration and testing of avionics instruments.
3. Demonstrate practical understanding of navigation, radar and communications.
4. Learn sensor integration to obtain useful flight data.
5. Integrate hardware and software used in aircraft systems.

Contents

1. Aircraft Electrical Power Systems: Generators, Alternators, APU
2. Pitot-Static Instrument Calibration: Airspeed vs Pressure study
3. Gyroscopic Instuments: IMU, drift minimization
4. Aircraft Communication Systems: Tune Communication Frequencies, Measure signal strength
5. Navigation systems: Aircraft states (heading, nose angle, roll angle display, turn to slip ratio)
6. Navigational Systems: Simulate VOR radial tracking, ILS , GPS
7. Radar Fundamentals: range calculation, doppler study
8. Flight control Servos: Control surface actuation at wing and tail rudder
9. Aircraft sensors: temperature sensors, Pressure and accelerometers integration
10. Study Cockpit: Pilot displays in different aircrafts
11. Flight control and autopilot setup
12. Fly by wire systems and ARINC

References:

1. Cary R. Spitzer, Uma Ferrell, Thomas Ferrell — *Digital Avionics Handbook,*CRC press, 3rd Edition (2014)
2. E. H. J. Pallett — *Aircraft Instruments and Integrated Systems*, Pearson Education, 1st Edition(2012 reprint)
3. Merrill I. Skolnik, Giuseppe A. Fabrizio, Gini Fulvio — *Radar Systems*, McGraw Hill, 4th edition revised (2006)

3rd year B.Tech. Aerospace Engineering
Curriculum Structure and Course Contents

VIth Semester

Title	**Propulsion-II**	Course No.	AExxxx
Department	Aerospace Engineering	L-T-P [C]	3–0–0 [3]
Offered for	B. Tech. (AE, ME);	Type	Core
Prerequisite	Thermodynamics		

Course Objectives

1. Introduce the essential fundamental and applied aspects of rocket propulsion – performance and design rationale
2. Classify various propulsion systems with their key applications
3. Describe the physical mechanisms and design principles for rocket engines
4. Appreciation of the application of rocket propulsion to flying vehicles

Learning Outcomes

1. Have a basic understanding of rocket propulsion concepts, their sub-variants, and understand how to select them based on the requirements
2. Identify the design constraints and perform a quick first-cut design or analysis of rocket engine and their components
3. Apply simple conservation principles to gain fast and deep insights into the behaviour of rocket propulsion systems

Contents

1. **Introduction & Review of Fundamentals [9 Lectures]:** History of rocket engine development, classification of different types, applications of rocket propulsion, review of conservation laws, Thrust equation, one-dimensional flow of gases through nozzle, nozzle configurations, energy and efficiency, typical performance values, flight performance, Single and multi-stage rocket systems, specific impulse, mass ratio, structural ratio, propellant mass fraction.
2. **Liquid propellant rocket engines [10 lectures] –** propellants, feed systems – pressure-fed vs pump-fed, propellant tanks, propellant properties, oxidizers and fuels, safety and concerns, turbopumps, engine design and control, ullage
3. **Combustion and Thrust Chambers [6 lectures] -** combustion process, heat transfer, analysis and simulations, combustion chamber, variable thrust, instabilities: pogo, chugging.
4. **Solid propellant rocket engines [10 lectures] –** propellant burning rate, propellant grain and grain configuration, hazards, motor case, igniter hardware
5. **Advanced propulsion [8 lectures]:** Hybrid propellant rockets, electric propulsion

Textbooks

1. George P. Sutton & Oscar Biblarz, "Rocket Propulsion Elements", Wiley 7th Edition
2. Philip Hill & Carl Peterson, "Mechanics and Thermodynamics of Propulsion", Pearson 2nd Edition

References

1. Dieter K. Huzel and David H. Huang, "Modern Engineering for Design of Liquid-Propellant Rocket Engines", American Institute of Aeronautics and Astronautics

Course Title	**Aerospace System Engineering**	Course No.	**AELXXX**
Department	Aerospace Engineering	L-T-P []	3-0-0 [3]
Offered for	B. Tech in Aerospace	Type	Core
Prerequisite			

Objectives

This course will expose students to a systematic methodology for designing complex aerospace systems with the help of examples, case studies.

Learning outcomes

1. Mathematical modeling of aerospace systems
2. Simulation of aerospace systems
3. Design and life cycle analysis of aerospace systems

Course Content

1. **Introduction [4 Lectures]:** Relevance of system integration with the help of examples from aerospace technology
2. **Definitions [4 Lectures]:** Definition of space systems, sub-systems, components, parts with examples
3. **Technical requirements definition [6 Lectures]:** Purpose, Types of requirements, Attributes of requirements, Requirements decomposition, Constraints, Performance measures
4. **System architecture [7 Lectures]:** Objective, Concept definition, Developing alternative concepts, Models of systems development lifecycle
5. **Design space exploration and optimization [12 Lectures]:** Model based system engineering, Trade-off studies and Design reviews, multi-objective optimization, Pareto optimality, multiple optimal solutions, robustness and sensitivity of optimal solutions to variations in design/control variables, and introduction to multidisciplinary problem-solving in aerospace systems.
6. **System integration [6 Lectures]:** Integrating parts and sub-systems into a functional system, system testing, verification, validation, reliability, and risk assessment.

Reference Books

1. B.N. Suresh and K. Sivan, Integrated Design for Space Transportation System, Springer, New Delhi, 2015
2. David D. Walden et al. (Eds.), Systems Engineering Handbook, Version 5, The International Council on Systems Engineering (INCOSE), Wiley, 2023. https://www.incose.org/publications/se-handbook-v5
3. MIT Open Course Ware (http://ocw.mit.edu): 16.842 Fundamentals of Systems Engineering, Fall 2009
4. http://ocw.mit.edu/courses/aeronautics-and-astronautics/16-842-fundamentals-of-systems-engineering-fall-2009/

Title	**Machine Learning for Aerospace Engineers**	Number	AELxxx0
Department	Aerospace Engineering	L-T-P [C]	3-1-0 [4]
Offered for	B.Tech A.E	Type	PC
Prerequisite	Introduction to Machine Learning		

Objectives:

1. To develop a deep understanding of how machine learning (ML) techniques can be systematically integrated with aerospace engineering physics to enhance modeling, prediction, control, diagnostics, and design of aerospace systems.
2. To prepare students to critically evaluate and apply state-of-the-art machine learning tools for aerospace engineering research and industrial applications.
3. To expose students to scientific machine learning approaches involving aerodynamics, propulsion, structures, controls, and autonomous aerospace systems.

Learning Outcomes:

1. Understand core ML algorithms and how to adapt them to aerospace problems.
2. Evaluate the quality, structure, and relevance of data for ML in aerospace applications.
3. Develop interpretable, physically-consistent ML models grounded in reliable experimental or simulation data.

Contents:

1. **Data and Aerospace Engineering (6 Lectures)**: Introduction to Machine Learning for Aerospace Engineering Applications; Aerospace Data Sources in Aerodynamics, Propulsion, Structures, and Control Systems; Aerospace Data Preprocessing and Feature Engineering; Evaluation Metrics; Computational Data Generation; Experimental Data Generation, and Measurement Techniques.
2. **Reduced Order Models (6 Lectures):** Principal Component Analysis (PCA); Proper Orthogonal Decomposition (POD); Dynamic Mode Decomposition (DMD), Spectral Proper Orthogonal Decomposition (SPOD); Applications to Unsteady Aerodynamics, Aeroelasticity, Flow Instabilities, and Flight Dynamics.
3. **Neural Network Architectures (10 Lectures)**: Physics-Informed Neural Networks (PINNs) for Governing Equations in Aerospace Systems; Long Short-Term Memory (LSTM) Networks; Convolutional Neural Networks (CNNs); Autoencoders; Transformer Architectures; Applications to: Unsteady Aerodynamics, Flight Dynamics, Flutter Analysis, Aerodynamic Load Prediction, Turbulent Flow Prediction
4. **Reinforcement Learning (RL) (5 lectures):** Fundamentals of RL for control applications; Deep RL (DRL) for Autonomous Flight Control; RL for Guidance Systems, and Flow control.
5. **Experimental Applications (6 Lectures)**: Digital Twins for Aircraft and Aeroengines; Aeroengine Diagnostics and Predictive Maintenance; Particle Image Velocimetry (PIV) Data Processing; Flow-Field Reconstruction from Sparse Experimental Measurements; Wind Tunnel and Flight-Test Data Analytics
6. **Case Studies (6 lectures)**: Airfoil Optimization; Autonomous UAV Navigation; Structural Health Monitoring; AI-Assisted Air Traffic; Gas Turbines; Hypersonic Systems; Additional case studies based on latest developments and not restricted to the above cases, Challenges, and future opportunities.

Text Books:

1. Géron, A. (2022). *Hands-on machine learning with Scikit-Learn, Keras, and TensorFlow*. O'Reilly Media, Inc.
2. Sutton, R. S, and Barton, A.G (2015). *Reinforcement Learning: An Introduction,* The MIT Press

Reference Material:

1. Mendez, M. A., Ianiro, A., Noack, B. R., & Brunton, S. L. (Eds.). (2023). Data-driven fluid mechanics: combining first principles and machine learning. Cambridge University Press.
2. Brunton, S. L., & Kutz, J. N. (2022). Data-driven science and engineering: Machine learning, dynamical systems, and control. Cambridge University Press

Self-Learning Material: https://www.youtube.com/@Eigensteve

Title	**Aircraft Design and Propulsion Lab**	Number	AEP4xxx
Department	Mechanical Engineering	L-T-P [C]	0-0-4[2]
Offered for	B. Tech. (AE);	Type	Core
Prerequisite	Nil		

Part A: Aircraft Design Lab

Course Objectives

1. To introduce students to the complete aircraft design cycle from mission definition to flight testing.
2. To provide hands-on experience in aerodynamic, structural, propulsion, and avionics subsystem design and integration.
3. To develop practical skills in fabrication, experimental testing, performance evaluation, and team-based engineering design.

Learning Outcomes

1. Design an aircraft configuration based on specified mission requirements and engineering constraints.
2. Analyze, fabricate, integrate, and experimentally validate major aircraft subsystems.
3. Conduct flight testing and evaluate aircraft performance against design predictions.

Contents

Lab 1: Mission Definition and Requirement Analysis
Lab 2: Conceptual Aircraft Configuration Design
Lab 3: Airfoil Selection and Wing Design
Lab 4: Aerodynamic Analysis and Stability Assessment
Lab 5: Propulsion System Selection and Thrust Testing
Lab 6: Aircraft Structural Design and Load Testing
Lab 7: Flight Control System and Avionics Integration
Lab 8: Fabrication and Manufacturing Techniques
Lab 9: Subsystem Integration and Ground Testing
Lab 10: Flight Testing and Trim Optimization
Lab 11: Performance Evaluation and Data Analysis
Lab 12: Final Demonstration and Design Review

Textbooks

1. Daniel P. Raymer, Aircraft Design: A Conceptual Approach, AIAA Education Series.
2. Jan Roskam, Airplane Design Series, DARcorporation.

Reference Books:

1. Snorri Gudmundsson, General Aviation Aircraft Design: Applied Methods and Procedures, Butterworth-Heinemann

Online Material:

- NASA Beginner's Guide to Aeronautics – https://www.grc.nasa.gov/www/k-12/airplane/
- XFLR5 Official Website – https://www.xflr5.tech/xflr5.htm

Part B: Propulsion Lab

Course Objectives

1. To introduce students to several practical aspects of propulsion devices
2. To introduce to pressure, temperature, flow measurement at point, line and using optical diagnostics
3. To introduce students to practical aspects of gas turbines, propellers, solid motors, sprays, and combustion phenomena

Learning Outcomes: After completion of this course, students should be able to:

1. Identify and interpret key aerothermodynamic features of different propulsion devices
2. Perform experiments and compare results to relevant theoretical benchmarks

Contents:

1. Study of propulsion lab safety, instrumentation, and engine test stand basics
2. Measure performance characteristics of a miniature turbojet
3. Map aerothermodynamic performance of a centrifugal compressor
4. Measure aerothermodynamic performance of an axial turbine stage
5. Determine laminar burning velocity as a function of equivalence ratio
6. Flame stability, blow-off, and flashback characteristics for gaseous fuels
7. Test injector characteristics of impinging-jet and swirl injectors
8. Map flow variable distribution along the length of a CD nozzle
9. Investigate performance of a small solid rocket motor
10. Investigate the effect of solid propellant grain design on motor performance
11. Measure the thrust produced by a propeller at different speeds

Textbooks

1. Aerospace Engineering Propulsion Lab Manual

References:

1. None

4th year B.Tech. Aerospace Engineering
Curriculum Structure and Course Contents

Program Electives

Course Title	**Atmospheric Fluid Dynamics**	Course No.	**AEL4XXX**
Offered for	Department of Aerospace, Mechanical, Civil and Infrastructural Engineering,	L-T-P	3-0-0 [3]
Pre-requisite	Thermodynamics, Fluid Mechanics/ Low-speed aerodynamics	Status	PE(Elective)

Objectives:

1. To develop a fundamental understanding of the Earth's climate system, atmospheric thermodynamics, radiative transfer, and the governing principles of atmospheric flows.
2. To provide theoretical and analytical knowledge of atmospheric waves, instabilities, turbulence, and boundary-layer processes for applications in atmospheric science.

Learning outcomes

1. Explain the structure and dynamics of the Earth's climate system and apply the principles of atmospheric thermodynamics to analyze atmospheric processes, energy balance.
2. Derive and analyze the governing equations of geophysical fluid dynamics and related concepts.
3. Analyze atmospheric turbulence and boundary-layer processes, including turbulent diffusion, eddy transport, surface energy balance, and the evolution of atmospheric boundary layers in environmental and geophysical flows.

Course Content

1. **Introduction [5 lectures]:** The components of the climate system- oceans, cryosphere, terrestrial biosphere, earth's crust and mantle, Role of various components in climate, Hydrological cycle, Carbon cycle, Brief history of climate and the earth system
2. **Atmospheric thermodynamics[8 lectures]:** Gas laws and Hydrostatic equation, Adiabatic processes, Water vapour in air, Static stability, First. Second law and entropy analysis of atmosphere, atmospheric dispersion
3. **Radiative transfer [4 lectures]:** EM spectrum, Radiation laws, Physics of absorption, emission and scattering, Radiative transfer in atmosphere, Planetary radiation budget, Introduction to Remote Sensing
4. **Geophysical Fluid Dynamics [7 lectures]:** The governing equations for the effect of rotation, stratification, and the thin layer equation for rotating spheres, Geostrophic flows theories, Ekman layers, Shallow water equations,
5. **Waves and Instabilities [6 lectures]:** Rossby Waves, Gravity Waves, Barotropic and Baroclinic instabilities, Interaction of waves with mean flow.
6. **Turbulence and Atmospheric Boundary Layer [9 lectures]:** The Kolmogorov Theory, Two-dimensional Turbulence, Spectra of Passive Tracers, Turbulent Diffusion and Eddy Transport, Geostrophic Turbulence and Baroclinic Eddies. The Surface Energy Balance and Vertical Structure in the Atmospheric Boundary Layer. Evolution and entrainment of Boundary-Layer Growth with Cloud-Topped Boundary Layer, Marine Boundary Layer and Stormy Weather.

Textbooks:

1. Wallace J. M. and HOBBS P. V., Atmospheric science: An Introductory Survey, Second Edition, Academic Press.
2. Vallis G. K., Atmospheric and Oceanic Fluid Dynamics: Fundamentals and Large-Scale Circulation, Second Edition, Cambridge University Press

Reference Books:

1. Andrews D. G., An Introduction to Atmospheric Physics, Second Edition, Cambridge University Press,
2. Murry S. L., Fundamentals of Atmospheric Physics, Academic Press.
3. Kundu, P. K., Cohen, I. M., Dowling, D. R., & Capecelatro, J. (2024). Fluid mechanics. Elsevier.

Online Self-Learning Material:

1. Introduction to Atmospheric Sciences, IIT Madras: https://nptel.ac.in/courses/119106008
2. Physics of Atmosphere and Ocean, IIT Delhi https://nptel.ac.in/courses/119102007
3. Introduction to Atmospheric and Space Sciences, IIT Roorkee https://nptel.ac.in/courses/115107121

Course Title	**Optical Diagnostics Techniques**	Course No.	**AEL4XXX**
Offered for	Department of Aerospace Engineering	L-T-P	3-0-0 [3]
Pre-requisite		Status	PE(Elective)

Objectives

1. To introduce students to various non-intrusive measurement tools using laser and optical methods.
2. To introduce students with various image processing techniques for flow visualisation and measurements.

Learning outcomes

1. Theoretical knowledge on conducting various laser and optical-based experimental measurements.
2. Knowledge to use advanced measurement tools for combustion, spray and supersonic flow research.

Course Content

1. **Introduction to Optics [4 Lectures]:** Fundamentals of geometrical and physical optics; reflection, refraction and Snell's law; focal length, magnification, depth of field and numerical aperture; image formation and aberrations; optical components and sheet optics: mirrors, beam splitters, prisms, optical filters, collimators, cylindrical lenses
2. **Introduction to lasers [5 Lectures]:** Stimulated emission, population inversion, laser cavities; continuous wave and pulsed lasers; Nd:YAG, Argon-ion, diode and femtosecond lasers; laser beam characteristics: coherence, monochromaticity, divergence and beam quality.
3. **Imaging systems and Characteristics [5 Lectures]:** CCD and CMOS cameras, streak cameras, ICCD cameras; lens selection for high-speed imaging, field of view, spatial and temporal resolution, exposure control and illumination considerations for flow diagnostics.
4. **Flow visualisation techniques [7 Lectures]:** Flow visualisation using light scattering and refraction: Mie scattering, Rayleigh scattering, Shadowgraph and Schlieren; Image processing for flow measurements: Background subtraction, Filtering, Flat Field Correction, Edge detection.
5. **Species concentration and Spray measurement [11 Lectures]:** Acetone Laser Induced Fluorescence (LIF); Measurement of Combustion species: LIF (OH, CH PLIF); 2 Line Planar Laser Induced Fluorescence (PLIF), Coherent anti-Stokes Raman Spectroscopy (CARS), Soot measurement: LII (laser induced incandescence); Direct laser sheet imaging, Phase Doppler Particle Analyzer (PDPA); Liquid LIF, shadowgraph and holographic techniques
6. **Laser-based Velocity and Temperature measurements [7 Lectures]:** Laser Doppler Velocimetry (LDV), Particle Image Velocimetry (PIV). Stereo-PIV, Measurement of planar temperature using laser-induced fluorescence, Thermal imaging: I-R cameras.

Textbooks:

1. Schulz, C., Dreizler, A., Wolfrum J., Combustion Diagnostics, Springer Handbook of Experimental Fluid Mechanics
2. Leipertz A., Pfadler S., and Schiebl R., An Overview of Combustion Diagnostics, Handbook of Combustion Vol.2: Combustion Diagnostics and Pollutants

Reference Books:

1. H.W. Coleman and W.G. Steele Jr., Experiments and Uncertainty Analysis for Engineers, Wiley & Sons, New York, 1989.
2. E.O. Doeblin, Measurement Systems, McGraw-Hill, New York, 1986.
3. R.J. Goldstein (Editor), Fluid Mechanics Measurements, Hemisphere Publishing Corporation, New York, 1983; second edition, 1996.
4. J. Hecht, The Laser Guidebook, McGraw-Hill, New York, 1986.
5. M. Lehner and D. Mewes, Applied Optical Measurements, Springer-Verlag, Berlin, (1999).

6. A.S. Morris, Principles of Measurement and Instrumentation, Prentice Hall of India, New Delhi, 1999.

Online Self-Learning Material:

1. M. Alde´n, J. Bood, Z. Li, M. Richter, Visualization and understanding of combustion processes using spatially and temporally resolved laser diagnostic techniques, Proceedings of the Combustion Institute 33 (2011) 69–97
2. R. K. Hanson, Combustion Diagnostics: Planar Imaging Techniques, Twenty-first Symposium (International) on Combustion/The Combustion Institute, 1986/pp. 1677-1691.
3. Dantec Dynamics, https://www.dantecdynamics.com/all-measurement-principles.

Course Title	**Fundamentals of Combustion**	Course No.	**AEL4XXX**
Offered for	Department of Aerospace, Mechanical, Civil and Infrastructural Engineering,	L-T-P	3-0-0 [3]
Pre-requisite	Thermodynamics	Status	PE(Elective)

Course Objectives

1. Introduce fundamental concepts related to combustion process
2. Understand governing equations, premixed flames, non-premixed flames
3. Understand turbulent combustion, emissions, chemical kinetics, and fuels

Learning Outcomes

After completion of this course, students should be able to:

1. Calculate the flame temperatures, understand chemical reactions
2. Analyse combustors using chemical reactor networks
3. Perform calculations that can help in designing combustors, understand flame stabilization and emissions

Contents

1. **Introduction to combustion & thermochemistry [5 lectures]:** Review of basic property relations, 1st law of thermodynamics, adiabatic flame temperatures, chemical equilibrium, mass transfbn er
2. **Chemical Kinetics [8 lectures]:** Global vs elementary reaction mechanisms, quasi-steady state and partial equilibrium assumptions, Arrhenius collision theory and reaction rates, chemical timescales, H2-O2 reaction mechanism, explosion limit diagram, importance of cross-over temperature, oxidation of hydrocarbons, methane combustion
3. **Chemical Reactor Networks [5 lectures]:** Fixed-mass reactor, well-stirred reactor, plug-flow reactor, conservations of mass, momentum, species transport equation, conservation of energy, mixture fraction.
4. **Laminar Premixed Flames [12 lectures]:** Physical description, simplified analysis, detailed analysis, scaling of flame speed with diffusion coefficient and reaction rates, factors influencing flame speed and thickness, quenching, flammability limits, flame stabilization, progress variable formulation, flame stretch, flame strain rates, extinction strain rate
5. **Non-premixed flames [9 lectures]:** Jet flames, conserved scalar approach, counterflow flames, scalar dissipation rate, extinction scalar dissipation rate, Crocco transformation, Flamelet hypothesis

Textbooks

1. S Turns, 3rd edition, “An Introduction to Combustion: Concepts and Applications”
2. I Glassman & R. A. Yetter, 4th edition, “Combustion”

References:

1. Aerospace Combustion – NPTEL series by Prof. Satya R. Chakravarthy

Course Title	**Boundary Layer Theory**	Course No.	**AEL4XXX**
Offered for	Department of Aerospace Engineering	L-T-P	3-0-0 [3]
Pre-requisite	Fluid Mechanics/Low-speed aerodynamics	Status	PE (Elective)

Objectives:

- To develop a fundamental understanding of laminar, thermal, transitional, and turbulent boundary layer flows and their role in momentum and heat transfer phenomena in engineering applications.
- To apply analytical and approximate methods for solving boundary layer equations and to analyze the effects of pressure gradients, instability, turbulence, compressibility, and flow control on boundary layer behavior.

Learning Outcomes

- Analyse laminar boundary layer flows over different geometries and evaluate important boundary layer parameters such as thickness, wall shear stress, drag, and separation characteristics.
- Apply similarity solutions, integral methods, and stability concepts to solve thermal, compressible, three-dimensional, and unsteady boundary layer problems.
- Interpret the mechanisms of laminar–turbulent transition and turbulent boundary layers, including their influence on momentum and heat transfer processes in practical fluid flow systems.

Contents

1. **Fundamentals of Boundary Layer Theory [5 lectures]:** Boundary Layer Concept, and Laminar Boundary Layer on a Flat Plate, Boundary Layer on an Airfoil, Separation of the Boundary Layer, Dimensional Representation, and Friction Drag.
2. **General Properties and Solutions of Boundary Layer Equations [7 lectures]**: Condition at the Wall, Similar Solutions of the Boundary–Layer Equations, Coordinate Transformation, Series Expansion of the Solutions, Asymptotic Behaviour of Solutions Downstream, Integral Relations, Approximate Methods for Solutions.
3. **Thermal Boundary Layer [8 lectures]**: Similarity Solutions of the Thermal Boundary Layer, Integral Methods for Computing the Heat Transfer, Boundary Layers with Moderate Wall Heat Transfer and Compressible Boundary Layers (Without Gravitational Effects), Natural Convection in Boundary Layer
4. **Three–Dimensional and Unsteady Boundary Layers and Their Control [8 lectures]:** Axisymmetric Boundary Layers , Boundary Layer at a cylinder, yawing cylinder, three–Dimensional Stagnation Point, Boundary Layers in Symmetry Planes, Similar and Semi–Similar Solutions for Small Times (High Frequencies) and Separation of Unsteady Boundary Layers. Integral Relations and Integral Methods, Unsteady Motion of Bodies in a Fluid at Rest, Unsteady Boundary Layers in a Steady Basic Flow, Different Kinds of Boundary–Layer Control.

5. **Laminar–Turbulent Transition in Boundary layer [5 lectures]:** Fundamentals of Stability Theory, Orr–Sommerfeld Equation, Curve of Neutral Stability for operating condition of Boundary Layer, Instability of the Boundary Layer for Three–Dimensional Perturbations
6. **Turbulent Boundary Layers [6 lectures]:** Fundamentals of Turbulent Flows, Turbulent Boundary Layers to the Temperature Field, Turbulent Boundary Layers with Coupling of the Velocity Field to the Temperature Field

Textbooks

1. Hermann Schlichting, Klaus Gersten, Boundary-Layer Theory, Ninth Edition, Springer

Reference books:

1. An Introduction to Fluid Dynamics, G. K. Batchelor, Cambridge University Press, 2010
2. Viscous Fluid Flow, F. M. White, McGraw Hill, USA, 1974
3. Fluid Mechanics, F. M. White, , McGraw Hill, USA, 1979

Course Title	**Boundary Layer Theory**	Course No.	**AEL4XXX**
Offered for	Department of Aerospace Engineering	L-T-P	3-0-0 [3]
Pre-requisite	Fluid Mechanics/Low-speed aerodynamics	Status	PE (Elective)

4. Fundamentals of Aerodynamics, John D. Anderson, , McGraw Hill, USA, 2007
5. Foundations of Aerodynamics, Kuethe and Chow, John Wiley & Sons Inc., 1976

Online Learning Material:

1. Introduction to Boundary Layers, IIT Madras https://nptel.ac.in/courses/112106190

Title	**Structural Health Monitoring**	Number	AEL4XXX
Department	Aerospace Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech (AE)	Type	Program Elective (PE)
Prerequisite	Solid Mechanics, Mechanics of Composite Materials		

Objectives:

1. The objective of this course is to provide students with a comprehensive understanding of the principles, technologies, and methodologies of Structural Health Monitoring (SHM) for engineering structures.
2. The course aims to develop a strong foundation in SHM philosophy, sensing mechanisms, data acquisition, and decision-making frameworks, with an emphasis on smart materials, including piezoelectric, magnetostrictive, and optical fiber sensors.

Learning Outcomes: The student will have ability to

1. Analyze local vibration and impedance-based SHM data using piezoelectric and smart material-based sensing techniques.
2. Select appropriate sensors, install SHM systems on real structures, and evaluate sensor performance and diagnostics.
3. Apply global vibration techniques to extract modal parameters such as natural frequencies and mode shapes for damage detection.

Contents-

Introduction to SHM [10 Lectures]: An overview of Structural Health Monitoring: definition, objectives, and philosophy. SHM framework: sensing, data acquisition, feature extraction, and decision making. SHM versus Non-Destructive Evaluation (NDE): similarities and differences. Levels of damage identification: detection, localization, quantification, prognosis. Overview of sensor systems and performance requirements for SHM. Smart materials for SHM: definition and classification. Piezoelectric materials: basic physics, constitutive relations, sensing and actuation. Magnetostrictive materials: fundamentals, magnetization and hysteresis behaviour. Optical fiber sensors and Lamb wave–based SHM methods. Emerging SHM technologies using piezo, magnetostrictive, and optical fiber sensors. Solution domain for SHM and commonly used damage indices. Overview of application potential of SHM in mechanical, aerospace, civil infrastructures, and other engineering systems.

Sensing and Data Acquisition System [10 Lectures]: Strain gauges, displacement sensors, accelerometers. Fiber Bragg Grating (FBG) sensors and optical sensing principles. Acoustic emission sensors and piezoelectric transducers. Embedded and surface-mounted sensors for composites, metals, and concrete. Wireless sensor networks, energy harvesting sensors, and sensor placement optimization. Data acquisition hardware/software and sampling requirements.

Structural Health Monitoring with Piezoelectric and Magnetostrictive Sensors [11 Lectures]: Sensor technology, Available industrial acousto-ultrasonic systems with piezoelectric sensors, Electro-Mechanical Impedance (EMI) technique, Delamination Sensing using Piezo Sensory Layer. Voltage response from Piezopatch. SHM using Magnetostrictive sensory layer. Basics of Magnetization and Hysteresis. Delamination sensing using Magnetostrictive sensory layer. Constitutive equation for the composite. Magnetostrictive sensory layer in symmetric laminate.

Structural Health Monitoring using Laser Doppler Velocimeter (LDV) or Vibrometer [8 Lectures]: Introduction to LDV. Experimental Modal Analysis using LDV. Linking experimental and analytical vibration data. Modal Assurance Criterion (MAC) for mode pairing. Velocity and Displacement Measurement using LDV. Mathematical description of structural system with damage. Damage localization and quantification. Case study for Symmetric and Cross-ply laminates.

Text Books:

1. Soh, C.K., Yang, Y. and Bhalla, S. eds., 2012. Smart materials in structural health monitoring, control and biomechanics. Springer Science & Business Media.

2. Bhalla, S., Moharana, S., Talakokula, V. and Kaur, N., 2017. Piezoelectric materials: applications in SHM, energy harvesting and biomechanics.

Reference Books:

1. Balageas, D., Fritzen, C.P. and Güemes, A. eds., 2010. Structural health monitoring (Vol. 90). John Wiley & Sons.
2. Gandhi, M.V. and Thompson, B.D., 1992. Smart materials and structures. Springer Science & Business Media.
3. Ewins, D.J., 2009. Modal testing: theory, practice and application. John Wiley & Sons.

Self-Learning Materials

1. Structural Health Monitoring, NPTE, https://nptel.ac.in/courses/114106046

Title	**Mechanics of Composite Materials**	Number	AEL7XXX
Department	Aerospace Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech. (AE)	Type	Program Elective (PE)
Prerequisite			

Objectives

1. The course aims to equip students with the ability to analyze and predict the elastic, thermal, and strength properties of composites using micromechanical and macromechanical approaches.
2. Emphasis is placed on anisotropy, orthotropic behavior, laminate mechanics, hygrothermal effects, and various shear deformation theories for static and dynamic analysis of composite beams, plates, and shells.

Learning Outcomes-

Upon successful completion of the course, students will be able to:

1. Identify and understand the basic mechanical behaviour of composite materials and make sound predictions on the likely behaviour of new combinations of materials.
2. Analyse the micromechanical properties of fibre reinforced composites.
3. Apply various theories for the static and dynamic analysis of composite structures.

Contents

Introduction to composites [3 Lectures]: Definitions, Composites, Reinforcements and matrices, Types of reinforcements, Types of matrices, Types of composites, Carbon Fibre composites, Glass Fibre composites, Graphite Fibre composites, Properties of composites in comparison with standard materials, Applications of metal, ceramic and polymer matrix composites.

Micromechanics of Composites [5 Lectures]: Density, Mechanical Properties; Prediction of Elastic Constants, Micromechanical Approach, Halpin-Tsai Equations, Transverse Stresses. Thermal Properties; Expression for Thermal Expansion Coefficients of Composites, Expression for Thermal Conductivity of Composites. Mechanics of Load Transfer from Matrix to Fiber; Load transfer in Particulate Composites.

Macromechanics of Composites [8 Lectures]: Elastic Constants of an Isotropic Material, Elastic Constants of a Lamina, Relationship between Engineering Constants and Reduced Stiffnesses and Compliances, Variation of Lamina Properties with Orientation. Local and global coordinate systems, Material Anisotropy, Material Symmetry, Orthotropic Laminate**,** Laminate Moduli, generalized Hooke's law, Characteristics of a unidirectional Lamina, Types of Laminates - Symmetric Laminates, Antisymmetric Laminate, Balanced Laminate, Quasi-isotropic Laminates, Cross-ply Laminate, Angleply Laminate, Hygrothermal Stresses.

Classical and First-Order Theories of Laminated Composite Plates [6 Lectures]: Classification of structural theories, assumptions, strain-displacement relation, lamina constitutive relations, equation of motion, laminate constitutive equations. Equation of motion in terms of displacements.

Static analysis of laminated composite structures (beams, plates and shells) using shear deformation theories [6 Lectures]: Governing equations. Bending and Buckling analysis of Beams, Plates and Shells. Analytical solution- Navier Solution and The Levy Solutions. Finite Element Method Solutions. MATLAB Programing implementation.

Dynamic analysis of laminated composite structures (beams, plates and shells) using shear deformation theories [6 Lectures]: Governing equations. Vibration analysis of Beams, Plates and Shells. Analytical solution- Navier Solution and The Levy Solutions. Finite Element Method Solutions. MATLAB Programing implementation.

Failure of Composites [5 Lectures]: Failure modes in composite lamina. Maximum stress and maximum strain criteria. Iterative failure criteria (Tsai-Hill, Tsai-Wu). Concept of first-ply failure and progressive failure. Comparative assessment of failure theories.

Text Books:

1. Agarwal, B.D., Broutman, L.J., Agarwal, B.D. and Broutman, L.J., 1990. Analysis and performance of fiber composites Second edition. John Wiley & Sons.
2. Reddy, J.N., 2003. Mechanics of laminated composite plates and shells: theory and analysis. CRC press.

Reference Books:

1. Jones, R.M., 2018. Mechanics of composite materials. CRC press.
2. Daniel, I.M., Ishai, O., Daniel, I.M. and Daniel, I., 1994. Engineering mechanics of composite materials (Vol. 3, pp. 256-256). New York: Oxford university press.

Self-Learning Materials-

1. Mechanics Of Fiber Reinforced Polymer Composite Structures, NPTEL, https://nptel.ac.in/courses/112103308
2. Composite Materials and Structures, NPTEL, https://archive.nptel.ac.in/content/storage2/courses/101104010/

Title	**Aero Elasticity**	Number	AEL4xxx
Department	Aerospace Engineering	L-T-P [C]	3–0–0 [3]
Offered for	B. Tech. (AE)	Type	Core
Prerequisite	Nil		

Course Objectives

- To introduce the fundamental concepts of aeroelasticity, including the interaction between aerodynamic forces, structural dynamics, and elastic deformations.
- To develop analytical and computational skills for modeling structural dynamics and aerodynamic loads in different flow regimes.
- To equip students with the ability to analyze and predict static and dynamic aeroelastic phenomena, such as divergence, control reversal, and flutter.

Learning Outcomes

- Explain the classification of aeroelastic problems and apply energy methods and structural modeling techniques for deformation analysis.
- Analyze aeroelastic stability issues, including divergence, control effectiveness, and flutter, using theoretical and computational approaches.
- Apply aerodynamic modeling techniques, such as Theodorsen's theory and finite state models, to evaluate unsteady aeroelastic effects in subsonic, transonic, and supersonic flow regimes

Contents

Aeroelasticity Concept [6 Lectures]: Aeroelastic problem definition, Collar diagram and classification of aeroelastic problems; Structural deformations; concept of influence coefficients and energy methods for deformation calculations, Principle of virtual work.
Structural Modelling [8 Lectures]: Lagrange's equation, Hamilton's principle; Formulation of dynamic equations for continuous structures e.g. beams, plates etc.; Differential eigenvalue problem, effect of boundary conditions, mode shapes and natural frequencies; Dynamic response of structures to general loading.
Aerodynamic Modelling [8 Lectures]: Subsonic, Transonic, and Supersonic flow conditions, Unsteady Potential flow theory, Theodorsen's theory and finite state model.
Static Aeroelasticity [9 Lectures]: Deformation-dependent aerodynamic forces, loss of static stability and the phenomenon of divergence; Control effectiveness and their reversal; Influence of sweep on divergence; Aeroelastic tailoring using composite structures.
Dynamic Aeroelasticity [8 Lectures]: 2-D quasi-static formulation of dynamic aeroelasticity and classical bending-torsion flutter; V-g method, p-k method, Modal flutter analysis, Panel Flutter, Finite Element Modelling for Aeroelastic system.

Text books

1. Dowell EH. A modern course in aeroelasticity. MECCANICA-MILANO-. 1999 Apr 1;34:140-.
2. Hodges DH, Pierce GA. Introduction to structural dynamics and aeroelasticity. cambridge university press; 2011 Aug 22.

Reference Book

1. Bisplinghoff RL, Ashley H, Halfman RL. Aeroelasticity. Courier Corporation; 2013 Jun 18.

Online study materials

1. NPTEL Lectures, Aero elasticity, IIT Kanpur, by Prof. C. Venkatesan. https://nptel.ac.in/courses/101104005

Title	**Basics of Finite Element Analysis**	Number	MEL4XX0
Department	Mechanical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech.	Type	PE
Prerequisite			

Objective:

1. To introduce the fundamentals of finite element analysis for one-dimensional engineering problems and develop finite element formulations from governing differential equations,
2. To provide hands-on experience in MATLAB/Python-based FEM implementation and validation using commercial simulation software.

Learning Outcomes: Upon successful completion of the course, students will be able to formulate and solve one-dimensional structural, thermal, and vibration problems using finite element methods. Students will also be able to implement FEM algorithms computationally and validate numerical results with analytical and commercial software solutions.

Contents:

Introduction [3 Lectures]: Historical development and scope of FEM, General steps involved in FEM, Applications, and advantages. Comparison of FE and exact solutions, Matrix notation, treatment of boundary conditions, and solution for the unknown degree of freedom. Matlab implementation.

Finite element formulation from governing differential equation [8 Lectures]: Weighted residual method, Use of single continuous trial function. General weighted residual statement. Weak (variational) form of the weighted residual statement. Comparison of differential equation, weighted residual and weak forms. Piecewise continuous trial function solution of the weak form. Rayleigh-Ritz Method, collocation method, Least square method, Galerkin approach.

Finite Element Formulation for One-Dimensional Problems [10 Lectures]: Local approximation function and global approximation function, convergence, continuity, and completeness. Compatibility. Weak form for bar with varying cross-section, 1D linear and higher order shape functions, Discrete equation, Local and global stiffness matrix, force vector from weak form. Numerical integration, Gauss quadrature, transformation from physical space to parent space. Matlab implementation. Verification with analytical solutions. Patch test.

FE-formulation for Beam elements [5 Lectures]: Beam theory, governing differential equation and boundary conditions, Weak formulation, Hermite shape function, Derivation of local stiffness matrix, and Force vector. Matlab implementation. Verification with analytical solutions.

Finite element analysis of time-dependent problems [5 Lectures]: Transient heat conduction equation, Weak formulation, FE-formulation. Finite difference approximation for time. Explicit and implicit schemes. MATLAB/Python implementation of transient heat conduction problems.

Finite element analysis eigenvalue problems and structural dynamics [8 Lectures]: Introduction to eigenvalue problems in engineering applications, free vibration of a rod, free vibration of a beam. Structural dynamics, governing differential equations for a bar, including the inertia term. Weak formulation. FE-formulation. Consistent mass matrix and Lumped mass matrix. Explicit and Implicit time integration scheme. Newmark's method. MATLAB/Python implementation of vibration problems.

Text books

1. Bathe, K.J., 2006. Finite element procedures. Klaus-Jurgen Bathe.
2. Fish, J. and Belytschko, T., 2007. A first course in finite elements (Vol. 1). New York: Wiley.

Reference books:

1. Reddy, J.N., 2026. An introduction to the finite element method. In Dynamics of Earth's Fluid System (pp. 199-226). CRC Press.
2. Hughes, T.J., 2003. The finite element method: linear static and dynamic finite element analysis. Courier Corporation.
3. Hutton, D., 2004. Fundamentals of finite element analysis. McGraw-Hill.
4. Cook, R.D., 2007. Concepts and applications of finite element analysis. John wiley & sons.
5. Seshu, P., 2003. Textbook of finite element analysis. PHI Learning Pvt. Ltd.

Online course material

1. https://nptel.ac.in/courses/112106135
2. https://onlinecourses.nptel.ac.in/noc20_me60/preview

Title	**Introduction to Mechatronics**	Number	AEL4XX0
Department	Mechanical Engineering/ Aerospace Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech.	Type	PE
Prerequisite			

Objective:

- To understand the multidisciplinary nature and scope of mechatronics engineering.
- To explain the roles of sensors, actuators, microcontrollers, and control systems in mechatronic products.
- To analyze basic mechanical, electrical, and electronic subsystems used in mechatronic systems.

Learning Outcomes:

After going through the course content student would be able to

- Analyze suitable sensors for measurements of displacement, pressure, acceleration, stress etc.
- Select suitable actuators and actuation technique
- Understand microcontroller architecture and its interaction with actuators and sensors.
- Apply feedback controller on actuator-sensor system.

Contents:

Introduction [3 Lectures]: Interdisciplinary Approach, Mechatronics system architecture, Real-life examples of Systems like Camera autofocus , washing machine and Air-Conditioner.

Sensors and Transducers[10 Lectures]: Position and displacement sensors (Potentiometers, LVDT and Encoders), Acceleration sensor, Force, Torque and Strain measurements, Pressure and flow sensors, Thermocouples, RTDs and Thermistors, Optical and proximity sensors,

Signal Conditioning of sensors [3 Lectures]: Analog and digital signals, Analog to digital converter, Sensor noise reduction, Filters and Data Acquisition system

Actuators and Drive systems[6 Lectures]: DC motors, stepper motors , pneumatic actuators, hydraulic actuators, DC motor drive and stepper motor drive.

Microcontroller and embedded system [3 Lectures]: Microcontroller architecture, input and output interfacing, sensor and actuation interfacing

Modelling of Mechanical Systems [8 Lectures]: Spring-mass-damper systems, simple and planetary gears, dynamic response of spring-mass-damper system and double pendulum system plotting using MATLAB/Python Coding. Understanding feedback and control of position.

Frequency and time-domain controls [6 Lectures]: Controller and stability criteria, poles and zeroes concept of stability , transfer function, Simulation of Control of inverted pendulum in time domain and in frequency domain using MATLAB/Python Coding

Text books

1. W. Bolton , Mechatronics: Electronic Control Systems in mechanical and electrical Engineering, Pearson Education, 7th Edition,2021
2. Godfrey C. Onwubolu, Mechatronics:Principles and Applications, Elseviers, 2005 .
3. David G. Alciatore and Michael B. Histand, Introduction to mechatronics and measurement systems, Mc Graw Hills, 6th edition , 2021

Reference books:

1. Devdas Shetty and Richard A. Kolk, Mechatronics System Design, Cengage Learning, 2nd Edition , 2010.

Online course material

1. nptel.ac.in/courses/112107298

Title	**Dynamics of Space Systems**	Number	AEL7xxx
Department	Aerospace Engineering	L-T-P [C]	3–0–0 [3]
Offered for	B. Tech. (ME and AE); M.Tech (TFE, ED, DADT, AE)	Type	Elective
Prerequisite	NIL		

Objectives

- Provide basic concept of space missions and role of launch vehicles and spacecraft in such missions, including their trajectory, configuration and orbital/re-entry solutions.

Learning Outcomes

- Formulate a realistic space mission starting from mission objectives
- Arrive at the configuration of the applicable launch system and its ascent trajectory
- Obtain the orbital / inter-planetary trajectory of spacecraft including their re-entry solutions

Contents

Part I: Launch Vehicle Trajectory Analysis and Configuration Design [19 Lectures]

Introduction [3 Lectures]: Space missions, definitions and role of ascent, orbital, inter-planetary and re-entry missions.
Ascent Mission Models [5 Lectures]: Ascent mission definition, Mission environment and applicable force models, General governing equations of ascent mission
Ascent Trajectory Analysis [7 Lectures]: Ideal motion solution, Rectilinear motion under gravity and atmospheric drag, Curvilinear motion solution under gravity turn assumption
Launch Vehicle Design [4 Lectures]: Launch vehicle sizing for a mission, Multi-stage vehicle concept and its design methodology, Concept of Launch Vehicle Variants

Part II: Spacecraft Orbits, Manoeuvres, Inter-planetary and Re-entry Solutions [23 Lectures]

Concept of Orbits [6 Lectures]: N-Body problem general formulation and two-body simplification, Central force motion solution and nature of orbits, orbits in geographical context and their determination from terminal conditions at the end of ascent mission
Orbital Manoeuvres [6 Lectures]: Apogee and perigee raising, Orbital plane changing, Hohmann transfer technique, Low thrust orbital transfers
Inter-planetary Motion Models [5 Lectures]: Three-body problem and concept of sphere of influence, Concepts of departure, Helio-centric motion and arrival, Orbital capture solutions
Docking & Re-entry Missions [6 Lectures]: Concept of launch window and fast transfers, Rendezvous and docking solutions, Re-entry / entry missions e.g. ballistic / lifting trajectories.

Textbook

1. Cornelisse et al, (1979), *Rocket Propulsion and Spaceflight Dynamics*, Pitman
2. Weisel (1997), *Spaceflight Dynamics*, McGraw Hill
3. Hale, (1994), *Introduction to Spaceflight*, Prentice Hall
4. Walter, (2012), *Astronautics: Physics of Spaceflight*, Wiley-VCH

Reference Books

1. Thompson, (1986), *Introduction to Space Dynamics*, Dover
2. Curtiss, (2010), *Orbital Mechanics for Engineering Students*, Elsevier

Online Course Material

1. Joshi, *Introduction to Launch Vehicle Analysis and Design,* NPTEL Course Material, Department of Aerospace Engineering, Indian Institute of Technology Bombay, http://nptel.ac.in/courses/noc22-ae06
2. https://www.nasa.gov/missions; https://www.isro.gov.in/missions; https://www.esa.int Web resources of major international space agencies.

Title	**Hypersonics Aerodynamics**	Number	AEL7XX0
Department	Mechanical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech. (AE)	Type	PE
Prerequisite	Fluid Mechanics/ Low speed Aerodynamics		

Objectives:

- To introduce the fundamental principles of hypersonic aerodynamics and high-temperature gas dynamics relevant to high-speed flight vehicles.
- To develop an understanding of shock waves, boundary layer interactions, viscous effects, and aerodynamic heating in hypersonic flows.
- To familiarize students with real gas effects, chemically reacting flows, and design considerations for hypersonic vehicles and propulsion systems.

Learning Outcomes:

- Analyze hypersonic flow fields involving shock waves, expansion waves, entropy layers, and viscous interactions using governing aerodynamic principles.
- Evaluate aerodynamic heating, high-temperature effects, and chemically reacting gas phenomena encountered in hypersonic flight.
- Apply hypersonic flow concepts to the design and analysis of re-entry vehicles, scramjet-powered systems, and thermal protection systems.

Contents:

Introduction and Review of Compressible Flows [6 Lectures]: Historical development of hypersonics, definition and characteristics of hypersonic flow, applications of hypersonic vehicles, review of thermodynamics, governing equations of compressible flow, review of 1-D isentropic flow equations, Normal and oblique shock waves, strong and weak shock solutions, Prandtl-Meyer expansion.

Inviscid Hypersonic Flow Fundamentals [7 Lectures]: Basic Hypersonic Shock Relations, Hypersonic Similarity Parameter, Hypersonic Expansion-Wave Relations; Local Surface Inclination Methods: Newtonian Flow, Modified Newtonian Flow, Tangent-Wedge and Tangent-Cone Methods, shock-expansion theory, pressure coefficient estimation, hypersonic flow over wedges and cones, aerodynamic coefficients at hypersonic speeds.

Hypersonic Inviscid Flow fields: Approximate and Exact Methods [6 Lectures]: Governing Equations, Mach-Number Independence, Hypersonic Small-Disturbance Equations, Hypersonic Equivalence Principle, Thin Shock-Layer Theory, Method of Characteristics

Shock Waves and Expansion Phenomena [5 Lectures]: Detached bow shocks, shock stand-off distance, curved shock waves, Prandtl-Meyer expansion in hypersonic flow, entropy layer effects, shock-shock interactions.

Viscous Hypersonic Flows [5 Lectures]: Navier–Stokes Equations., Hypersonic boundary layers, laminar and turbulent boundary layers, Boundary-Layer Equations for Hypersonic Flow, Self-Similar Solutions,, strong viscous interaction, entropy layer swallowing, boundary layer transition in hypersonic flow, separation phenomena, shock-boundary layer interactions, skin friction and drag estimation.

Hypersonic Propulsion and Re-entry Aerothermodynamics [6 Lectures]: Fundamentals of air-breathing hypersonic propulsion, ramjet and scramjet engines, supersonic combustion principles, fuel injection and mixing, ignition and flame stabilization, inlet compression systems, isolator; Aerodynamic Heating and Thermal Protection: Physical mechanisms of aerodynamic heating, convective and radiative heating, stagnation point heating, heat transfer correlations, thermal boundary layer, thermal protection systems (TPS), ablative cooling, reusable TPS materials, heat shield design considerations.

Experimental and Computational Techniques [4 Lectures]: Hypersonic wind tunnels and shock tunnels, flow visualization techniques, pressure and heat transfer measurements, basics of CFD for hypersonic flows, turbulence modeling challenges, numerical treatment of shocks and reacting flows.

Text books

1. John D. Anderson Jr., Hypersonic and High Temperature Gas Dynamics, AIAA

Reference books:

1. John J. Bertin, Hypersonic Aerothermodynamics, AIAA.

Online course material: http://www.digimat.in/nptel/courses/video/101105333/L01.html

Title	**Atomizations and Sprays**	Number	AEL7XXX
Department	Aerospace Engineering	L-T-P [C]	3-0-0 [3]
Offered for	M.Tech (ME)/ Ph.D.	Type	Program Elective (PE)
Prerequisite	Fluid Mechanics/Low-speed Aerodynamics		

Objectives:

- To introduce students to the necessary theory to understand spray formation and evolution, as well as a host of spray applications.
- To enable students to understand atomizations and spray processes in gas turbine engines, geo-engineering, internal combustion engine sprays and the use of non-traditional liquids in aero-propulsion and other systems.

Learning Outcomes:

- Understand the fundamental physics, governing equations and parameters in atomization and sprays.
- Analyse and interpret the results of droplet size and velocity distribution from experimental techniques for spray characterisation and measurement.
- Evaluate the sheet and droplet breakup mechanics in different atomisers and sprays for combustion and propulsion applications.
- Apply conservation laws and force balance principles to predict droplet motion, interaction, collision, coalescence, and evaporation phenomena in sprays.

Contents:

1. **Introduction [2 lectures]:** Basic spray processes, Factors controlling spray formation.
2. **Drop size and velocity distribution functions [4 lectures]**: Number distributions, Mass/volume distributions, Empirical distributions, Theoretical distributions.
3. **Sheet and ligament breakup and Drop formation[11 lectures]:** Instability analyses for ligaments and sheets, Design models based on instability analyses. Static and dynamic force balances, Continuity considerations, Secondary atomization, Collisions and coalescence.
4. **Drop motion, interactions and evaporation [7 lectures]:** Steady trajectories (gas turbines, spray cooling, paint sprays), Entrainment. Steady evaporation, Unsteady evaporation, Convective effects
5. **Internal and external flow in sprays fluid mechanics [7 lectures]:** Swirl atomizers, Impinging jet atomizers, Cone angle, Radial and circumferential mass flux distributions.
6. **Atomizer performance [4 lectures]:** Modern design models for pressure-swirl atomizers, impinging jet atomizers, transient pressure (Diesel) atomizers.

7. **Measurement techniques [4 lectures]:** Drop sizing by Malvern and P/DPA, Drop velocity by P/DPA, Mass flux distribution via patternators and P/DPA.

Text Books:

1. Atomization and Sprays, by A.H. Lefebvre (Hemisphere: New York, 1989. ISBN 0-89116-603-3)

Reference Book

1. Liquid Atomization, by L. Bayvel and Z. Orzechowski (Taylor and Francis: Washington DC, 1993. ISBN 0-89116-959-8).

Self-Learning Materials:

1. NPTEL course "Introduction to sprays and their applications" https://nptel.ac.in/courses/112106154