



**DAYANANDA SAGAR
UNIVERSITY**



**SCHOOL OF
ENGINEERING**

2023-27 Batch

BACHELOR OF TECHNOLOGY (B. Tech) –2023

Aerospace Engineering

(With effect from 2024-25)

**Devarakaggalahalli, Harohalli, Kanakapura Road, Ramanagara Dt.,
Bengaluru 562 112, Karnataka**

III SEMESTER

S.N	Program Code	Course Code	Course Name	Teaching Department	Teaching Hours / Week				Examination				Credits
					Lecture	Tutorial	Practical	Project	Duration in Hours	CIE Marks	SEE Marks	Total Marks	
					L	T	P	J					
1	101	23AS2301	Transforms and Numerical Techniques	MAT	3	0	0	0	3	60	40	100	3
2	101	23AS2302	Thermodynamics and Heat Transfer	ASE	3	1	0	0	3	60	40	100	4
3	101	23AS2303	Introduction to Aerospace Engineering	ASE	2	0	0	0	3	60	40	100	2
4	101	23AS2304	Fluid Mechanics	ASE	3	1	0	0	3	60	40	100	4
5	101	23AS2305	Aerospace Structural Mechanics	ASE	3	0	2	0	3	60	40	100	4
6	101	23AS2306	Aerospace Materials	ASE	3	0	2	0	3	60	40	100	4
7	101	23LSXXXX	Liberal Studies/MOOC	Any Dept.	1	0	0	0	1	100	--	100	1
8	101	23AS2307	Skill Enhancement Course - I	ASE	0	0	2	0		100	--	100	1
9	101	23AS2308	Cognitive and Technical Skills-I		0	0	4	0	-	100	--	100	2
			Total		18	2	10	0		560	240	900	25

IV SEMESTER

S.N	Program Code	Course Code	Course Name	Teaching Department	Teaching Hours / Week				Examination				Credits
					Lecture	Tutorial	Practical	Project	Duration in	CIE Marks	SEE Marks	Total Marks	
					L	T	P	J					
1	101	23AS2401	Probability and Statistics	MAT	3	0	0	0	3	60	40	100	3
2	101	23AS2402	Aerodynamics	ASE	3	1	0	0	3	60	40	100	4
3	101	23AS2403	Aircraft Propulsion	ASE	3	0	0	0	3	60	40	100	3
4	101	23AS2404	Space Flight Mechanics	ASE	3	0	0	0	3	60	40	100	3
5	101	23AS2405	Aerospace Manufacturing	ASE	3	0	2	0	3	60	40	100	4
6	101	23AS2406	Introduction to Computational Fluid Dynamics	ASE	1	0	2	0	2	60	40	100	2
7	101	23AS2407	Skill Enhancement Course - II	ASE	0	0	2	0	-	100	--	100	1
8	101	23AS2408	Cognitive and Technical Skills -II		0	0	4	0	-	100	---	100	2
			Total		16	1	10	0		560	240	800	22

TRANSFORMS AND NUMERICAL TECHNIQUES

[As per the Choice Based Credit System (CBCS) scheme]

SEMESTER - III

Subject Code	: 23AS2301	Credits	: 03
Hours / Week	: 03 Hours	Total Hours	: 39 Hours
L-T-P-S	: 3-0-0-0		

Course Learning Objectives:

This Course will enable students to:

1. **Apply** their knowledge of Laplace transforms and inverse Laplace transforms to proficiently solve linear ordinary differential equations with constant coefficients, facilitating the analysis and modelling of complex systems.
2. **Analyze** periodic functions using Fourier series, assessing the convergence properties and precision of the series expansion, thereby enhancing their ability to understand and manipulate periodic phenomena.
3. **Utilize** complex exponential form, Fourier transforms of basic functions, and Fourier sine and cosine transforms to solve problems involving Fourier integrals, developing proficiency in applying these techniques to various mathematical scenarios.
4. **Employ** numerical methods, including Euler's Method, Runge-Kutta 4th order, Adams-Bashforth, and Adams-Moulton Methods, to solve differential equations and effectively analyze dynamic systems, enabling them to model real-world phenomena and make accurate predictions.
5. **Apply** finite difference methods, including the Crank-Nicolson method and appropriate techniques for hyperbolic PDEs, to effectively solve different types of partial differential equations (PDEs) such as elliptic, parabolic, and hyperbolic equations, enhancing their problem-solving skills in the context of differential equations and their applications.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

1. **Lecture method** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
2. **Interactive Teaching: Adopt the Active learning** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
3. Show **Video/animation** films to explain functioning of various concepts.
4. Encourage **Collaborative** (Group Learning) Learning in the class.
5. To make **Critical thinking**, ask at least three Higher order Thinking questions in the class.
6. Adopt **Problem Based Learning**, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
7. Show the **different ways to solve** the same problem and encourage the students to come up with their own creative ways to solve them.
8. Discuss how every **concept can be applied to the real world** - and when that's possible, it helps improve the students' understanding.

UNIT - I :Laplace Transform and Inverse Laplace Transform

09 Hours

Laplace Transforms of Elementary functions (without proof), (**Text Book-1: Chapter 6: 203 to 207**).

Laplace Transforms of $e^{at}f(t)$, $t^n f(t)$ and $\frac{f(t)}{t}$, Periodic functions, Unit step function and impulse functions (**Text Book-1: Chapter 6:208-230**).

Inverse Laplace Transforms- By the method of Partial Fractions, Logarithmic and Trigonometric functions, Convolution Theorem, Inverse Laplace transform using Convolution Theorem (Text Book-1: Chapter 6: 238). Solution to Differential Equations by Laplace Transform. (Text Book-1: Chapter 238-242).	
UNIT – II: Fourier Series	09 Hours
Periodic Functions, Trigonometric Series (Text Book-1: Chapter 11: 495). Fourier series Standard function, Functions of any Period 2L, Even and Odd functions, Half-range Expansions. (Text Book-1: Chapter 11: 483-492) Practical Harmonic analysis (calculate average power and RMS values of periodic waveforms)	
UNIT – III: Fourier Transform	06 Hours
Calculation of Fourier integrals using complex exponential form (Text Book-1: Chapter 11: 510). Fourier transform of basic functions (Text Book-1: Chapter 11: 510-516). Fourier sine and cosine transforms. (Text Book-1: Chapter 11: 518-522).	
UNIT – IV: Numerical Methods for Solving Ordinary Differential Equations	07 Hours
Euler's Method-Basic principles of Euler's method for solving first-order ODEs (Text Book-1: Chapter 1:10-12). Runge-Kutta 4th order (Text Book-1: Chapter 21:904). Multistep Methods-Explanation of multistep methods (Adams-Bashforth, Adams–Moulton Methods) (Text Book-1: Chapter 21:911-913). Second-Order ODE. Mass–Spring System (Euler Method, Runge–Kutta Methods) (Text Book-1: Chapter 21:916-918).	
UNIT – V: Numerical Methods for Partial Differential Equations	08 Hours
Classification of PDEs (elliptic, parabolic, hyperbolic), (Text Book-1: Chapter 21:922-923). Finite Difference Methods (Laplace and Poisson Equations), Derivation of finite difference approximations (Text Book-1: Chapter 21:923-927). Crank–Nicolson Method (Text Book-1: Chapter 21:938-941). Method for Hyperbolic PDEs (Text Book-1: Chapter 21:943-945).	

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	Apply Laplace transforms and inverse Laplace transforms to solve linear ordinary differential equations with constant coefficients, demonstrating proficiency in system analysis and modelling.	L3
2	Analyze periodic functions using Fourier series and evaluate the convergence properties and precision of the series expansion.	L2 & L3
3	Solve problems involving Fourier integrals by applying complex exponential form, Fourier transforms of basic functions, and Fourier sine and cosine transforms.	L3
4	Utilize numerical methods such as Euler's Method, Runge-Kutta 4th order, Adams-Bashforth, and Adams-Moulton Methods to solve differential equations and analyze dynamic systems	L2 & L3
5	Apply finite difference methods, including the Crank-Nicolson method and appropriate techniques for hyperbolic PDEs, to solve various types of partial differential equations (PDEs) such as elliptic, parabolic, and hyperbolic equations.	L3

Table: Mapping Levels of COs to POs / PSOs														
COs	Program Outcomes (POs)												PSOs	
	1	2	3	4	5	6	7	8	9	10	11	12	1	2
C01	3	2	2	1					1					
C02	3	2	2						1					
C03	3	2	2	1					1					
C04	3	2	2	1					1					
C05	3	2	2	1					1					

3: Substantial (High)

2: Moderate (Medium)

1: Poor (Low)

TEXT BOOKS:

1. Erwin Kreyszig, Advanced Engineering Mathematics, 2015, 10th Edition, Wiley India.

REFERENCE BOOKS:

1. Higher Engineering Mathematics, B.S. Grewal, 2015, 43rd Edition, Khanna Publishers.
2. Higher Engineering Mathematics, John Bird, 2017, 6 th Edition, Elsevier Limited.

E-Resources:

1. <https://nptel.ac.in/courses/111106139>
2. <https://nptel.ac.in/courses/111101164>
3. <https://nptel.ac.in/courses/111105038>

THERMODYNAMICS AND HEAT TRANSFER

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – III

Subject Code	: 23AS2302	Credits	: 04
Hours / Week	: 03 Hours	Total Hours	: 39+13 Hours
L-T-P	: 3-1-0		

Course Learning Objectives:

This course will enable students to:

1. **Apply** thermodynamic laws to open and closed systems
2. **Analyze** phase change of pure substances.
3. **Apply** thermodynamic laws to heat engines, heat pumps and refrigerators.
4. **Derive** fundamental relations between thermodynamic properties.
5. **Apply** ideal cycle analysis to Otto, Diesel, Bryton cycle and refrigeration cycles.
6. **Analyze** the different heat transfer mechanisms.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teachers can use to accelerate the attainment of the various course outcomes.

1. **Lecture method** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
2. **Interactive Teaching: Adopt the Active learning** that includes brainstorming, discussing, group work, focused listening, formulating questions, note taking, annotating, and roleplaying.
3. Show **Video/animation** films to explain the functioning of various concepts.
4. Encourage **Collaborative** (Group Learning) Learning in the class.
5. To make **Critical thinking**, ask at least three Higher-order Thinking questions in the class.
6. Adopt **Problem Based Learning**, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
7. Show the **different ways to solve** the same problem and encourage the students to come up with their own creative ways to solve them.
8. Discuss how every **concept can be applied to the real world** - and when that's possible, it helps improve the students' understanding.

Course Content

UNIT – I

08 Hours

Basic Concepts of Thermodynamics:

Introduction- Basic Concepts: System, Control Volume, Surrounding, Boundaries, Universe, Types of Systems, Macroscopic and Microscopic viewpoints, Concept of Continuum, Thermodynamic Equilibrium, Thermodynamic properties: definition and units. Intensive and extensive properties. Thermodynamic state, state point, path and process, quasi-static process, cyclic and non-cyclic processes, Energy and its forms, Work and heat (sign convention), irreversible process, causes of irreversibility, Zeroth law of thermodynamics statement, Concept of Temperature and its measurement, Temperature scales.

UNIT – II

08 Hours

First Law of Thermodynamics:	
Forms of energy, Heat and Work, types of work, First Law of Thermodynamics, energy balance, energy change of a system, energy and environment. Application of the first law of thermodynamics to a closed and open system, Internal energy and enthalpy, specific heats, energy as a property, Steady Flow Energy Equation, Application of SFEE, Properties of Pure Substances, phases of a pure substance, property diagrams for phase change process of pure substance.	
UNIT – III	08 Hours
Second Law of Thermodynamics:	
Limitations of the first law of thermodynamics, Thermal reservoirs, Heat engines, Thermal Efficiency, reversed heat engine, Refrigerator and Heat Pump, Coefficient of Performance, Kelvin-Planck and Clausius statement of the second law of thermodynamics, Equivalence of the two statements, reversible and irreversible processes, Carnot theorem and its corollaries. Entropy, an increase of entropy principle; third law. Entropy change for ideal gases. The Tds relations, general relations for du, dh, ds, specific heats	
UNIT – IV	08 Hours
Gas Power and Refrigeration Cycles:	
Ideal Cycles - Otto cycle, Diesel cycle and Joule-Brayton cycle: Refrigeration Cycles: Vapor compression refrigeration, air refrigeration cycles. Open cycle aircraft cooling system.	
UNIT – V	07 Hours
Introduction to Heat Transfer:	
Thermodynamics and Heat Transfer, Applications, Historical background, Heat transfer modes, Conduction, Fourier law, Thermal conductivity, diffusivity, Convection; Newton's law of cooling, Radiation heat transfer, Simultaneous heat transfer mechanisms, Overall heat transfer coefficient.	

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course, the student will be able to:		
1	Analyze temperature scales using Zeroth law of thermodynamics.	L2 & L3
2	Analyze the work and heat interactions and perform first law analysis of various processes.	L2 & L3
3	Apply the second law of thermodynamics and entropy concepts for analyzing heat engines, refrigerators and heat pumps	L2 & L3
4	Apply ideal cycle analysis to heat engine and refrigeration cycles to determine performance parameters.	L2 & L3
5	Apply governing laws of conduction, convection and radiation heat transfer to determine heat transfer rate and temperature.	L2 & L3

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)												PSOs	
	1	2	3	4	5	6	7	8	9	10	11	12	1	2
C01	3	2	1									1	3	
C02	3	2												
C03	3	2	1									1	2	
C04	3	3	2	1	2		1					1	3	
C05	3	1			1								2	

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. Cengel, Y., and Boles, M., "Thermodynamics: An Engineering Approach", 9th Ed., McGraw Hill, 2018
2. Sonntag, R. E., Borgnakke, C. and Van Wylen, G. J., "Fundamentals of Thermodynamics", 6th ed., Wiley, 2002

REFERENCE BOOKS:

1. Nag, P. K., "Engineering Thermodynamics", 4th ed., Tata McGraw Hill, 2008
2. Cengel, Y., and Ghajar, "Heat transfer: A practical approach", McGraw Hill, 2nd Ed., 2002
3. Michael J. Moran, Howard N. Shapiro, Daisie D. Boettner, Margaret B. Bailey, "Fundamentals of Engineering Thermodynamics", 9th Edition, Wiley, 2018

E-Resources:

1. <https://www.coursera.org/learn/thermodynamics-intro>
2. <https://nptel.ac.in/courses/127106135>

INTRODUCTION TO AEROSPACE ENGINEERING

SEMESTER – III

Subject Code	:	23AS2303		Credits	:	02
Hours / Week	:	02 Hours		Total Hours	:	26 Hours
L-T-P	:	2-0-0				

Course Learning Objectives:

This course will enable students to:

1. Describe the key historical developments and milestones in aerospace engineering
2. Explain the principles of aerodynamics and its application to aircraft and spacecraft design
3. Analyse the fundamental principles of propulsion systems used in aerospace vehicles.
4. Display proficiency in the role of key aircraft structures and systems
5. Demonstrate awareness of the recent trends and developments in the aerospace industry and career opportunities

1. Teaching-Learning Process (General Instructions)

2. These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.
3. **Lecture method** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
4. **Interactive Teaching: Adopt the Active learning** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
5. Show **Video/animation** films to explain functioning of various concepts.
6. Encourage **Collaborative** (Group Learning) Learning in the class.
7. To make **Critical thinking**, ask at least three Higher order Thinking questions in the class.
8. Adopt **Problem Based Learning**, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
9. Show the **different ways to solve** the same problem and encourage the students to come up with their own creative ways to solve them.
10. Discuss how every **concept can be applied to the real world** - and when that's possible, it helps improve the students' understanding.

UNIT – I

06 Hours

INTRODUCTION TO AEROSPACE ENGINEERING

Definition, scope, and importance of aerospace engineering - Civil, military and commercial Aerospace, Historical overview and key milestones in aerospace technology, Introduction to space sector, satellite & spacecraft technologies

Overview of the aerospace industry –Key stakeholders: Tier 1, Tier 2 and Tier 3 manufacturers, airlines, regulators and standards, Aerospace revenue model and economy, public and private sector players

UNIT – II

04 Hours

FUNDAMENTALS OF FLIGHT AERODYNAMICS

Atmosphere, Basic principles of aerodynamics, airfoils, lift generation, and drag. Forces acting on an aircraft, classification of aircraft, aircraft nomenclature, flight control surfaces, Speed of sound, Mach Number, subsonic, supersonic and hypersonic flight	
UNIT – III	06 Hours
AIRCRAFT PROPULSION & ROCKET PROPULSION	
Concept of Thrust, Piston engines and propellers, Basics of jet engine – components and basic working principle, Brayton cycle, Jet engine types - turboprop, turbojet, turbofan, turboshaft, Efficiency measures (specific fuel consumption, thrust-to-weight ratio), Ramjets and scramjets, Rocket propulsion, classification, specific impulse	
UNIT – IV	06 Hours
AIRCRAFT STRUCTURES & SYSTEMS	
Nomenclature of aircraft structures and their functions, Metallic and composite materials and their uses in aircraft structures, Basic aircraft instruments and displays, the meaning of the term ‘avionics’, Introduction to hydraulic, pneumatic and electrical systems – Air conditioning and cabin pressurization, electric power (generation, distribution, motors), fuel management, fire, ice, rain and lightning protection, landing gear, lighting systems, aircraft interiors, cargo and actuation systems.	
UNIT – V	04 Hours
ADVANCEMENTS IN THE AEROSPACE INDUSTRY	
Aircraft industry trends and case studies – connected aircraft, PHM- prognostics and health monitoring, AI and digital twins, Space Industry trends - Spacecraft, satellite systems, space exploration, applications and missions, reusable rockets, space debris, Unmanned Aircraft Systems – Technologies and Applications, Environmental concerns and sustainability, circularity, Defence sector – Integration of domains: air, land, sea (surface and sub-surface), space, cybersecurity, and electromagnetic spectrum	

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	Outline historical developments in the aerospace industry and identify the key aircrafts and spacecraft industry stakeholders	L2 & L3
2	Apply key physical concepts to flight principles including aerodynamics, aircraft forces and controls	L2 & L3
3	Compare the working of different aircraft and rocket propulsion systems.	L2 & L3
4	Integrate the roles of various aircraft structures and systems	L2 & L3
5	Analyse important trends and advances in aerospace sector	L3, L4

Table: Mapping Levels of COs to POs / PSOs														
COs	Program Outcomes (POs)												PSOs	
	1	2	3	4	5	6	7	8	9	10	11	12	1	2
CO1	3	2										1	2	
CO2	3	2										1	3	
CO3	3	2	1									1	3	
CO4	3	2	2									1	3	
CO5	3	2				2	2					1	3	

TEXTBOOKS:

1. John D. Anderson, "Introduction to Flight", McGraw-Hill Education, 8th edition, 2015, ISBN: 978-0078027673.
2. E Rathakrishnan, Theoretical Aerodynamics, 2013 Edition, John Wiley & Sons, Singapore, ISBN: 9781118479346.

REFERENCE BOOKS:

1. Ian Moir, Allan Sea bridge, "Aircraft Systems: Mechanical, Electrical and Avionics Subsystems Integration", John Wiley & Sons, 3rd edition, 2011, ISBN: 9781119965206.
2. Sutton G.P., "Rocket Propulsion Elements", John Wiley, New York, 9th edition, 2016, ISBN: 9781118753910.
3. A.C. Kermode, "Flight without formulae", Pearson Education India, 5th edition, 1989, ISBN: 9788131713891.
4. Fundamentals of Aerospace Engineering: An Introductory Course to Space and Aerospace Technology by Manuel Soler ISBN13: 9781493727759
5. James R. Wertz and Wiley J. Larson "Space Mission Analysis And Design", 3rd Edition (Space Technology Library) Microcosm Publications ISBN-13: 978-1881883104

FLUID MECHANICS [As per Choice Based Credit System (CBCS) scheme] SEMESTER – III			
Subject Code	: 23AS2304	Credits	: 03
Hours / Week	: 03 Hours	Total Hours	: 52 Hours
L-T-P-C	: 3-1-0-4		
Course Learning Objectives: This Course will enable students to: 1. Analyze the incompressible fluid flow by different governing equations 2. Explain the basic properties of fluids, and hydrostatic forces. 3. Understand dimensional analysis and its application. 4. Describe the boundary layer flow of fluid.			
Teaching-Learning Process (General Instructions) These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes. 1. Lecture method means it includes not only traditional lecture method, but different <i>type of teaching methods</i> may be adopted to develop the course outcomes. 2. Interactive Teaching: Adopt the Active learning that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying. 3. Show Video/animation films to explain functioning of various concepts. 4. Encourage Collaborative (Group Learning) Learning in the class. 5. To make Critical thinking, ask at least three Higher order Thinking questions in the class. 6. Adopt Problem Based Learning, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it. 7. Show the different ways to solve the same problem and encourage the students to come up with their own creative ways to solve them. 8. Discuss how every concept can be applied to the real world - and when that's possible, it helps improve the students' understanding.			
UNIT – I			08 Hours
INTRODUCTION: Introduction, properties of fluids, surface tension and capillarity. Fluid pressure at a point, Pascal's law, pressure variation in a static fluid, absolute, gauge, atmospheric and vacuum pressures, simple manometers. Application area of fluid mechanics, pressure variation in a static fluid. Hydrostatics-Center of pressure, center of buoyancy and meta center.			
UNIT – II			08 Hours
FLUID FLOW AND FLUID KINEMATICS: Methods of describing fluid motion, Lagrangian and Eulerian descriptions, types of fluid flow, continuity equation in 3 dimensions, velocity potential function and stream function. Types of motion, Source sink, doublet, plotting of stream lines and potential lines Numerical problems, Vorticity. Vortex motion: Helmholtz law, Biot Savart Law, Kelvin circulation theorem, Vortex sheet.			
UNIT – III			06 Hours
FLUID DYNAMICS: Introduction, Euler's Equation of motion, Assumptions, Bernoulli's equation, Bernoulli's equation for real fluids and application, Measurement of flow, venturimeter, orifice meter, pitot tube			

UNIT – IV		09 Hours
DIMENSIONAL ANALYSIS: Dimensional homogeneity, methods of dimensional analysis, model analysis, types of similarity and similitude. Dimensionless numbers. Model laws. Numerical problems..		
UNIT – V		08 Hours
BOUNDARY LAYER THEORY: Equation of motion in differential form, Viscous flow, exact solutions, pipe flow. Laminar boundary layers. Boundary layer solution methods. Introduction to Turbulence, Reynolds averaging		

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	Apply governing laws to different types of fluid flows and determine variation of pressure and velocity for different boundary conditions	L2 & L3
2	Determine stream function, circulation and vorticity.	L2 & L3
3	Apply Euler's Equation and Bernoulli's equation to determine flow parameters in flow measuring devices-venturi meter, orifice meter and rotometer.	L2 & L3
4	Use the concepts of dimensional homogeneity, and similitudes and determine various non-dimensional quantities.	L2 & L3
5	Apply the boundary layer theory to determine turbulence parameters	L2 & L3

Table: Mapping Levels of COs to POs / PSOs														
COs	Program Outcomes (POs)												PSOs	
	1	2	3	4	5	6	7	8	9	10	11	12	1	2
CO1	3	3											1	
CO2	3	3			1								1	
CO3	3	3			1				3	3			1	
CO4	3	3											1	
CO5	3	3											1	

3: Substantial (High)

2: Moderate (Medium)

1: Poor (Low)

TEXT BOOKS:

1. White, F. M., "Fluid Mechanics (SI Units)", 7th Ed., Special Indian Edition, McGraw Hill, 2011.
2. Cengel, Y.A., Cimbala J. M., "Fluid Mechanics (Fundamentals and Applications)", 2nd Ed., Tata McGraw Hill, 2010

REFERENCE BOOKS:

1. Dr. R.K. Bansal, (2000), "Fluid Mechanics and Hydraulic Machines", Laxmi Publication (P) Ltd., New Delhi.
2. P.N. Modi and S.M. Seth (1999), "Hydraulics and Fluid Mechanics including Hydraulic Machines", Standard Book House, Naisarak, Delhi
3. Panton, R. L., "Incompressible Flow", 3rd Ed., Wiley India Edition, 2006.

E-Resources:

1. <https://archive.nptel.ac.in/courses/112/105/112105171/>
2. <https://www.vlab.co.in/participating-institute-nitk-surathkal>

AEROSPACE STRUCTURAL MECHANICS			
SEMESTER – III			
Subject Code : 23AS2305		Credits : 04	
Hours / Week : 03 Hours		Total Hours : 39 + 26 Hours	
L-T-P : 3-0-2			
Course Learning Objectives:			
This course will enable students to:			
1. Analyze the behaviour of aerospace structures under different loading conditions			
2. Apply principles of structural analysis to determine the stress, strain, and deformation of aerospace components and systems.			
3. Evaluate the performance and safety of aerospace structures by conducting structural integrity assessments and failure analyses.			
4. Interpret and analyze experimental data obtained from structural tests, such as material testing, load testing, and vibration analysis.			
1. Teaching-Learning Process (General Instructions)			
2. These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.			
3. Lecture method means it includes not only traditional lecture method, but different <i>type of teaching methods</i> may be adopted to develop the course outcomes.			
4. Interactive Teaching: Adopt the Active learning that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.			
5. Show Video/animation films to explain functioning of various concepts.			
6. Encourage Collaborative (Group Learning) Learning in the class.			
7. To make Critical thinking , ask at least three Higher order Thinking questions in the class.			
8. Adopt Problem Based Learning , which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.			
9. Show the different ways to solve the same problem and encourage the students to come up with their own creative ways to solve them.			
10. Discuss how every concept can be applied to the real world - and when that's possible, it helps improve the students' understanding.			
UNIT – I			08 Hours
FLIGHT VEHICLE STRUCTURES			
Principles of structures construction: Materials, Properties of material, material selection for aerospace structure applications, Analysis of aircraft structures, loads on structural components and their function, structures, fabrication, airworthiness and airframe loads, fatigue.			
UNIT – II			08 Hours
BASIC STRESS ANALYSIS			
Concepts, types of stresses and strains, Stress-strain relations in 1D, 2D, and 3D, Plane stress and strain, Principal stresses, Lateral strain, Poisson's ratio and volumetric strain, Elastic moduli			

UNIT - III	06 Hours
STRESSES IN BEAMS Definition of beam - Types of beams, loads and reactions, Shear force and Bending moment and their diagrams, bending stress, shear stress and deflection in the beam	
UNIT - IV	09 Hours
TORSION Torsion of a solid section, hollow sections and thin-walled sections. Shear Centre torsion equations	
UNIT - V	08 Hours
STRUCTURAL DESIGN PRINCIPLES Buckling and stability, critical load, Euler's column theory, types of end condition, combined bending and torsion, Equivalent stress, Working stress, a factor of safety, failure theories, analysis of composite materials	

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	Determine loads on aircraft structural members and select appropriate material.	L2 & L3
2	Analyze the axial members for stress, strain and deformation	L2 & L3
3	Construct Shear force and bending moment diagrams and calculate bending and shear stresses in beams.	L3 & L4
4	Analyze the torsional members for stress, strain and deformation.	L3 & L4
5	Determine critical load for columns with different end conditions.	L2 & L3
6	Apply the theories of failure in designing the structures	L2 & L3

Table: Mapping Levels of COs to POs / PSOs														
COs	Program Outcomes (POs)												PSOs	
	1	2	3	4	5	6	7	8	9	10	11	12	1	2
CO1	3	3		2	1								3	
CO2	3	3	2	3	2				2	2			2	
CO3	3	3		3	2				2	2		1	2	
CO4	3	3	2	2	2				2	2		1	2	
CO5	3	3		2	2				2	2		1	2	
CO6	3	3		2	2								2	

3: Substantial (High)

2: Moderate (Medium)

1: Poor (Low)

TEXT BOOKS:

1. T.H.G. Megson, Aircraft Structures for Engineering students, Elsevier. 5th edition, 2007.
2. Lalit Gupta and O P Sharma, Fundamentals of Flight Vol-II (AIRCRAFT STRUCTURES), Himalayan Books. 2006, ISBN: 9788170020752

REFERENCE BOOKS:

1. J.B.K. Das and Dr. P.L.Srinivas Murthy , “Mechanics of Materials”, Sapna, 2016.
2. Barry J Goodno, James M Gere, Mechanics of Materials, 9th Edition, Cengage Publications

E-Resources:

1. <https://archive.nptel.ac.in/courses/101/105/101105084/>

Activity-Based Learning (Suggested Activities in Class)

1. Group discussions on finding the root causes of failure of aircraft component
2. Video demonstrations on building a spacecraft and group discussions

AEROSPACE STRUCTURES LABORATORY**Total Contact Hours: 26**

The following experiments to be carried out

1. Column Test: The column test is carried out to study the behaviour of structural columns under axial loads.
2. Deflection of Beams: This experiment involves studying the deflection behaviour of beams under different loads.
3. Thin and Thick-Walled Pressure Vessel: This experiment involves analyzing the behaviour of pressure vessels subjected to internal or external pressure.
4. Photoelastic Test: The photoelastic test is used to analyze stress distribution in transparent materials.
5. Fatigue Testing: Fatigue testing is performed to assess a material's resistance to repeated or cyclic loading.
6. The vibration of Beams: This experiment involves studying the vibration characteristics of beams subjected to dynamic loads.
7. Creep Testing Machine: The creep testing machine is used to evaluate a material's behaviour under long-term constant stress or load.
8. Pin Jointed Frames Analysis: This experiment involves analyzing the structural behaviour of pin-jointed frames subjected to various loads.
9. Determinate Beam Structure: This experiment involves analyzing statically determinate beam structures subjected to different loads
10. Case study of the failure of aircraft structures

AEROSPACE MATERIALS

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – III

Subject Code	: 23AS2306	Credits	: 4
Hours / Week	: 03 Hours	Total Hours	: 39+ 26 Hours
L-T-P	: 3-0-2		

Course Learning Objectives:

This course will enable students to:

1. **Analyze** the different material requirements which are intended to the global aerospace industry and market
2. **Devise** the testing of different materials and apply the same based on strength and durability criteria.
3. **Explain** the time-temperature relationship and different types of heat treatment processes for various metals and alloys and concepts of corrosion in materials
4. **Get the idea** of basic principles of metallurgy, advanced materials for jet engine applications and thermal barrier coating applications.
5. **Describe** and illustrate different materials for composite materials manufacturing and introduction of materials for additive manufacturing, aerospace, marine, automotive and domestic applications.

1. Teaching-Learning Process (General Instructions)

2. These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.
3. **Lecture method** for this course includes presentation which includes **chalk and talk for all modules**.
4. **Interactive Teaching: The adoption of Active learning via brainstorming for module 1 and 2 are of group discussion which is based on selection of materials for different applications.**
5. The concept in each and every module consists of **video animations** which utilises virtual labs for testing of materials.
6. The **collaborative learning** which will be group oriented which involves development of composites materials using different fabrication techniques.
7. The **Critical thinking** is adopted considering time and temperature transformation diagram which is of different measures for different materials
8. Adopt **Problem Based Learning**, in this course is based on solving numerical based on strength and durability testing of materials which will be experimentally and theoretically validated.
9. Different methods of **solving problems** involves different case studies based on wings, etc in an aircraft.
10. Discuss how every **concept can be applied to the real world** – In this courses an attempt is made for a development of wing structure via concept of shape memory alloys which involves light metal alloys like titanium, aluminium and magnesium alloys.

UNIT – I

07 Hours

INTRODUCTION TO AEROSPACE MATERIALS

Brief history of aerospace materials, Materials for the global aerospace industry and market, Types, Future advances in aerospace materials, Material requirements for aerospace structures and engines, Introduction to Fixed-wing aircraft structures, Helicopter structures, Space shuttle structures, satellite structures

UNIT – II

08 Hours

TESTING OF AEROSPACE MATERIALS Strengthening of metal alloys: Introduction, Crystal structure of metals, Defects in crystal structures, strengthening of metal, Corrosion of aerospace metals Introduction to Tension test, Compression test, Flexure test, Hardness test, Fracture test, Drop-weight impact test, Fatigue test, Creep test, Environmental durability testing, certification of aerospace materials, Non-Destructive Testing (NDT)	
UNIT – III	08 Hours
LIGHT METAL ALLOYS Aluminum alloys for aircraft structures: Introduction, Aluminum alloy types, Heat treatment of aluminum alloys, High-temperature strength of aluminum, Introduction to Titanium alloys and their applications, Types of titanium alloy, Titaniumaluminides, Shape memory titanium alloys, Introduction to Magnesium alloys and their applications, types, Metallurgy of magnesium alloys	
UNIT – IV	08 Hours
STEELS & SUPER ALLOYS Steels for aircraft structures: Introduction, Basic principles of steel metallurgy, Maraging steel, Medium-carbon low-alloy steel, Stainless steel, Super alloys for gas turbine engines: Introduction, Nickel-based super alloys, Iron–nickel super alloys, Cobalt super alloys, Thermal barrier coatings for jet engine alloys, advanced materials for jet engines	
UNIT – V	08 Hours
CERAMICS & COMPOSITE MATERIALS Introduction, modern ceramic materials, cermets, glass ceramic, production of semi-fabricated forms, Applications of Composites, Fibers, Resin and other materials for composite manufacturing, Introduction to polymer matrix composites, metal matrix composites, ceramic matrix composites, and carbon fibre composites.	

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	Outline the requirements of materials for aerospace vehicle components.	L2& L3
2	Interpret results from the Tension test, Compression test, Flexure test, Hardness test, Fracture test, Drop-weight impact test, Fatigue test, Creep test, Environmental durability testing, certification of aerospace materials, Non-Destructive Testing.	L3 & L4
3	Describe the heat treatment of aluminum alloys, High-temperature strength of aluminum, Introduction to Titanium alloys and their applications, Types of titanium alloy, Titaniumaluminides, Shape memory titanium alloys,	L2 & L3
4	Identify the principles of steel metallurgy, Maraging steel, Medium-carbon low-alloy steel, Stainless steel, Super alloys for gas turbine engines and thermal barrier coating applications.	L2 & L3
5	Describe the Applications of Composites, Fibers, Resin and other materials for composite manufacturing.	L2

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)												PSOs	
	1	2	3	4	5	6	7	8	9	10	11	12	1	2
CO1		2	1										3	
CO2	3	3	1				1						2	
CO3	3	3			1									2
CO4														2
CO5		3	1											2

3: Substantial (High)

2: Moderate (Medium)

1: Poor (Low)

TEXT BOOKS:

1. Adrian P. Mouritz, "Introduction to aerospace materials", Wood head Publishing Limited, 2012, ISBN 978-1-85573-946-8
2. George E. Dieter "Mechanical Metallurgy", McGraw Hill Publications
3. William D. Callister, "Materials Science and Engineering: an Introduction", John Wiley and sons

REFERENCE BOOKS:

1. Brian Cantor, Hazel Assender and Patrick Grant, "Aerospace Materials", Institute of Physics Publishing, ISBN: 0 7503 0742
2. Sam Zhang, Dongliang Zhao "Aerospace Materials Handbook" CRC Press Taylor & Francis Group, ISBN: 978-1-4398-7330

E-Resources:

1. <https://archive.nptel.ac.in/courses/113/102/113102080/>
2. <https://sm-nitk.vlabs.ac.in/List%20of%20experiments.html>

Activity-Based Learning (Suggested Activities in Class)

1. Group discussions on new emerging materials in aircraft industry
2. Video demonstrations different materials and manufacturing process for an aircraft.

MATERIALS TESTING LABORATORY

Total Contact Hours: 24

Following are experiments to be carried out at Materials Testing Laboratory.

1. Hardness Test: The hardness test is performed to determine the resistance of a material to indentation or scratching
2. Tensile test: The tensile test is conducted to measure the mechanical properties of a material under tension.
3. Compression test: The compression test is carried out to evaluate the behaviour of a material under compressive forces
4. Impact Test: The impact test is used to assess a material's ability to absorb energy under high velocity impact.
5. Bending test: The bending test is performed to evaluate the behaviour of a material under bending loads.
6. Shear Test: The shear test is conducted to measure the strength of materials against shear forces.
7. Demonstration of Reinforcements & Matrix materials applied to aerospace industry.
8. Demonstration of Laser cutting and Engraving for space craft structures.
9. Design & Modelling of Aircraft Components using Master Cam Software.
10. Case Studies on aircraft design and manufacturing followed by site visit.

SEMESTER – IV

PROBABILITY AND STATISTICS

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – IV

Subject Code	: 23AS2401	Credits	: 03
Hours / Week	: 03 Hours	Total Hours	: 39 Hours
L-T-P	: 3-0-0		

Course Learning Objectives:

This Course will enable students to:

1. **Apply** statistical principles and probability concepts to solve complex problems in real-world scenarios involving uncertainty and randomness.
2. **Evaluate** and select appropriate probability distributions and statistical techniques to analyze and interpret data accurately in various applications.
3. **Justify** the use of estimation methods and hypothesis testing techniques for drawing meaningful inferences about population parameters.
4. **Analyze** and interpret sample test results for different statistical relationships, such as means, variances, correlation coefficients, regression coefficients, goodness of fit, and independence, to make informed decisions.
5. **Identify** sample tests using appropriate statistical procedures to investigate the significance of observed data and communicate findings effectively.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

9. **Lecture method** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
10. **Interactive Teaching: Adopt the Active learning** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
11. Show **Video/animation** films to explain functioning of various concepts.
12. Encourage **Collaborative** (Group Learning) Learning in the class.
13. To make **Critical thinking**, ask at least three Higher order Thinking questions in the class.
14. Adopt **Problem Based Learning**, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
15. Show the **different ways to solve** the same problem and encourage the students to come up with their own creative ways to solve them.
16. Discuss how every **concept can be applied to the real world** - and when that's possible, it helps improve the students' understanding.

UNIT – I : Probability	09 Hours
Definitions of Probability, Addition Theorem, Conditional Probability, Multiplication Theorem, Bayes' Theorem of Probability	
UNIT – II: Random Variables and their Properties and Probability Distributions	09 Hours
Discrete Random Variable, Continuous Random Variable, Joint Probability Distributions Their Properties, Probability Distributions: Discrete Distributions: Binomial, Poisson Distributions and their Properties; Continuous Distributions: Exponential, Normal, Distributions and their Properties.	
UNIT – III: Estimation and testing of hypothesis	06 Hours

Sample, Populations, Statistic, Parameter, Sampling Distribution, Standard Error, Un-Biasedness, Efficiency, Maximum Likelihood Estimator, Notion & Interval Estimation.	
UNIT – IV: Sample Tests-1	07 Hours
Large Sample Tests Based on Normal Distribution , Small Sample Tests : Testing Equality of Means, Testing Equality of Variances, Test of Correlation Coefficient	
UNIT – V: Sample Tests-2	08 Hours
Test for Regression Coefficient; Coefficient of Association, 2 – Test for Goodness of Fit, Test for Independence.	

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	Apply the principles of probability to solve complex problems in various real-world scenarios.	L2 & L3
2	Solve and compare different probability distributions, including discrete and continuous random variables, in order to make informed decisions and predictions.	L2 & L3
3	Apply statistical estimation techniques, such as maximum likelihood estimation and interval estimation, to draw meaningful inferences about population parameters from sample data.	L3
4	Examine hypothesis testing methods, including large and small sample tests, to assess the significance of observed data and draw valid conclusions.	L4
5	Analyze statistical relationships and perform sample tests to assess the Equality of means in different populations, Correlation coefficients between variables to determine the strength and direction of the relationship. Independence of variables using appropriate statistical tests to assess the absence of any relationship.	L4

Table: Mapping Levels of COs to POs / PSOs														
COs	Program Outcomes (POs)												PSOs	
	1	2	3	4	5	6	7	8	9	10	11	12	1	2
C01	3	2	2		2				1					
C02	3	2	2		2				1					
C03	3	2	2						1					
C04	3	2	2		2				1					
C05	3	2	2		2				1					

TEXT BOOKS:

1. Probability & Statistics for Engineers and Scientists, Walpole, Myers, Myers, Ye. Pearson Education.

REFERENCE BOOKS:

3. Probability, Statistics and Random Processes T. Veerarajan Tata McGraw – Hill
4. Probability & Statistics with Reliability, Queuing and Computer Applications, Kishor S. Trivedi, Prentice Hall of India ,1999

E-Resources:

1. <https://nptel.ac.in/courses/106104233>
2. <https://nptel.ac.in/courses/117103067>
3. <https://nptel.ac.in/courses/103106120>
4. <https://www.coursera.org/learn/probability-intro#syllabus>
5. <https://nptel.ac.in/courses/111104073>

Activity Based Learning (Suggested Activities in Class)

1. Tools like Python programming, R programming can be used which helps student to develop a skill to analyze the problem and providing solution.
2. Regular Chapter wise assignments/ Activity/Case studies can help students to have critical thinking, developing an expert mind set, problem-solving and teamwork.

Following are Activities Can carried out in place of Assignments using either R programming language or Python Programming or excel solver.

1. There are n people gathered in a room. What is the probability that at least 2 of them will have the same birthday? (Use excel solver, R Programming, Python Programming)
 - a. Use simulation to estimate this for various n , and Produce Simulation Graph.
 - b. Find the smallest value of n for which the probability of a match is greater than 0.5.
 - c. Explore how the number of trials in the simulation affects the variability of our estimates.

2. Case Study 1: Customer Arrivals at a Coffee Shop

- a. Background: A coffee shop wants to analyze the number of customer arrivals during its morning rush hour (7:00 AM to 9:00 AM). The shop has been recording the number of customer arrivals every 15 minutes for the past month.
- b. Data: The data consists of the number of customer arrivals recorded at the coffee shop during each 15-minute interval for the past month.
- c. Here is a sample of the data:

Time Interval	Customer Arrivals
7:00 AM - 7:15 AM	6
7:15 AM - 7:30 AM	4
7:30 AM - 7:45 AM	9
7:45 AM - 8:00 AM	7
8:00 AM - 8:15 AM	5
8:15 AM - 8:30 AM	8

8:30 AM - 8:45 AM	10
8:45 AM - 9:00 AM	6

analyze the customer arrivals and determine the probability distribution that best fits the data. Specifically, explore both discrete and continuous probability distributions, including the binomial, Poisson, exponential, and normal distributions.

3. Case Study 2: Comparing the Performance of Two Groups

- Suppose you are a data analyst working for a company that manufactures a new energy drink. The marketing team conducted a promotional campaign in two different cities (City A and City B) to determine the effectiveness of the campaign in increasing sales. The sales data for a random sample of customers in each city was collected over a week. Your task is to compare the average sales between the two cities and test whether there is a significant difference in the variance of sales.

- Data: Let's assume the following sample data for the number of energy drinks sold in each city:

City A: [30, 28, 32, 29, 31, 33, 34, 28, 30, 32]

City B: [25, 24, 26, 23, 22, 27, 29, 30, 26, 24]

perform a two-sample t-test to test the equality of means and a test for equality of variances using Python's SciPy library.

4. case study 3: testing independence between two categorical variables.

- Data: Sample of 100 employees, and each employee is classified as either Male or Female. They were asked to rate their job satisfaction on a scale of 1 to 5, where 1 represents low satisfaction and 5 represents high satisfaction. The data is as follows:

Employee	Gender	Job Satisfaction
1	Male	4
2	Female	3
3	Male	2
4	Female	5
...	...	...
100	Female	4

- Test for independence between gender and job satisfaction, use the chi-squared test in R.

AERODYNAMICS			
[As per Choice Based Credit System (CBCS) scheme]			
SEMESTER – IV			
Subject Code : 23AS2402		Credits : 03	
Hours / Week : 03 Hours		Total Hours : 39 + 13 Hours	
L-T-P : 3-1-0			
<u>Course Learning Objectives:</u>			
This Course will enable students to:			
1. Understand the applications of basic laws of conservation of mass, momentum and energy as applied to aerodynamics 2. Use of transformations to solve basic flows and their superposition leading to inviscid theories of flow past objects, concepts of Vorticity, Irrotationality and Potential Flows 3. Explain the theory of lift generation due to circulation around airfoils 4. Apply the conservation laws to compressible flows 5. Explain the characteristics of normal and oblique shock waves and expansion waves.			
Teaching-Learning Process (General Instructions)			
These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.			
1. Lecture method means it includes not only traditional lecture method, but different <i>type of teaching methods</i> may be adopted to develop the course outcomes. 2. Interactive Teaching: Adopt the Active learning that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying. 3. Show Video/animation films to explain functioning of various concepts. 4. Encourage Collaborative (Group Learning) Learning in the class. 5. To make Critical thinking, ask at least three Higher Order Thinking questions in the class. 6. Adopt Problem Based Learning, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it. 7. Show the different ways to solve the same problem and encourage the students to come up with their own creative ways to solve them. 8. Discuss how every concept can be applied to the real world - and when that's possible, it helps improve the students' understanding.			
UNIT – I		10 Hours	
INCOMPRESSIBLE FLOW OVER AIRFOILS:			
Elementary flows, Vortex flow, Lifting flow over a circular cylinder, Kutta-Joukowski theorem and generation of Lift, D-Alembert's paradox. Airfoil Nomenclature, Airfoil Characteristics, Kutta condition, Kelvin's circulation theorem, Classical Thin Airfoil Theory: The Symmetric Airfoil, The Cambered Airfoil, The Aerodynamic Center, Modern Low-Speed Airfoils, Viscous Flow: Airfoil Drag			
UNIT – II		08 Hours	
INCOMPRESSIBLE FLOW OVER FINITE WINGS:			
Introduction: Downwash and Induced Drag, The Vortex Filament, the Biot-Savart Law, and Helmholtz's Theorems, Prandtl's Classical Lifting-Line Theory, Applied Aerodynamics: The Flow over an Airfoil—The Real Case, Applied Aerodynamics: The Delta Wing			
UNIT – III		07 Hours	
Applications of Finite Wing Theory & High Lift Systems:			
Simplified horse-shoe vortex model, formation flight, influence of downwash on tail plane, ground effects. Swept wings: Introduction to sweep effects, swept wings, pressure coefficient, typical aerodynamic characteristics,			

Subsonic and Supersonic leading edges. Introduction to high-lift systems, flaps, leading-edge slats and typical high – lift characteristics. Critical Mach numbers, Lift and drag divergence, Effects of thickness, camber and aspect ratio of wings.	
UNIT – IV	06 Hours
Compressible Flow: Definition of Compressibility, Governing Equations for Inviscid, Compressible Flow, Definition of Total (Stagnation) Conditions, Speed of Sound, Mach number, Area-velocity relation, Area Mach number relation, nozzles and diffusers. Basics of Normal Shock Wave, Calculation of Normal Shock-Wave Properties, Use of Tables to Solve Compressible Flow Problems.	
UNIT – V	08 Hours
Oblique Shock and Expansion Waves: Oblique Shock Relations, Supersonic Flow over Wedges and Cones, Prandtl-Meyer Expansion Waves, Shock-Expansion Theory: Applications to Supersonic Airfoils, Calculation of Lift and Drag Coefficients.	

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course, the student will be able to:		
1	Use the theory of elementary flows to analyze flow over different geometries.	L2 & L3
2	Analyze ideal and real aerodynamic characteristics of flow over wing surfaces at low speeds	L2 & L3
3	Apply finite wing theory for designing high lift systems.	L2 & L3
4	Explain isentropic compressible flows in variable area ducts and apply them in the analysis of nozzles and diffusers	L3 & L4
5	Use normal shock relations to calculate flow properties across the shock wave.	L3 & L4
6	Analyze oblique shock and expansion waves	L2 & L3

COs	Program Outcomes (POs)												PSOs	
	1	2	3	4	5	6	7	8	9	10	11	12	1	2
C01	3	3			2								3	
C02	3	3		1	2								3	
C03	3	3			1								2	
C04	3	2		1	2								2	
C05	3	3	1	2	1					1			3	1
C06	3	2	1		1					1			2	2

3: Substantial (High)

2: Moderate (Medium)

1: Poor (Low)

TEXT BOOKS:

1. Anderson, J.D., “Fundamentals of Aerodynamics”, McGraw Hill Book Co., 1999
2. E Rathakrishnan, Theoretical Aerodynamics, Published by John Wiley and Sons, Singapore, 2013
3. Houghton, E.L., and Caruthers, N.B., “Aerodynamics for Engineering students”, Edward Arnold Publishers Ltd., London, 1989

REFERENCE BOOKS:

1. Horowitz E., Sahni S., Rajasekaran S, "Computer Algorithms", Galgotia Publications, 2001.
2. R.C.T. Lee, S.S. Tseng, R.C. Chang & Y.T.Tsai, "Introduction to the Design and Analysis of Algorithms A Strategic Approach", Tata McGraw Hill, 2005.

E-Resources:

1. <https://youtu.be/KqfYobOYRTc>
2. <https://youtu.be/gLPJAjyiUxA>
3. <https://youtu.be/4qppw7d07kM>
4. <https://youtu.be/AarN5AmIhjY>

Activity Based Learning (Suggested Activities in Class)

1. Real world problem solving and puzzles using group discussion, e.g., Sports aerodynamics, Automotive and Industrial aerodynamics

AIRCRAFT PROPULSION

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – IV

Subject Code : 23AS2403	Credits : 03
Hours / Week : 03 Hours	Total Hours : 39 Hours
L-T-P : 3-0-0	

Course Learning Objectives:

This course will enable students to:

1. **Perform** cycle **analysis** and **determine** the performance parameters of propulsion systems - turbojet, turbofan and turboprop configurations.
2. **Understand** the design principles of inlets, combustion chambers, and nozzles used in aircraft propulsive systems.
3. **Understand** the working principles of gas turbines and **determine** the performance characteristics of compressors and turbines.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teachers can use to accelerate the attainment of the various course outcomes.

1. **Lecture method** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
2. **Interactive Teaching: Adopt the Active learning** that includes brainstorming, discussing, group work, focused listening, formulating questions, note taking, annotating, and roleplaying.
3. Show **Video/animation** films to explain the functioning of various concepts.
4. Encourage **Collaborative** (Group Learning) Learning in the class.
5. To make **Critical thinking**, ask at least three Higher-order Thinking questions in the class.
6. Adopt **Problem Based Learning**, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
7. Show the **different ways to solve** the same problem and encourage the students to come up with their own creative ways to solve them.
8. Discuss how every **concept can be applied to the real world** - and when that's possible, it helps improve the students' understanding.

Course Content

UNIT – I

12 Hours

Introduction to Propulsion Techniques:

Aircraft propulsive devices – piston-prop, turbojet, turboprop, turbofan, turbo-shaft and ramjet engines; Propfans/Unducted fan engines; Engine thrust and performance parameters- Specific fuel consumption, thermal, propulsive and overall efficiencies. Factors affecting thrust and power. Ideal Cycle analysis of turboprop, turbojet and turbofan engine components.

UNIT – II

07 Hours

Inlets and Nozzles:

Power plant Installation types - Wing Installation, Fuselage Installation, Combined Wing and Tail Installation, Combined Fuselage and Tail Installation.

The Flight Mach Number and Its Impact on Inlet Duct Geometry, Diffusers, An Ideal Diffuser, Subsonic Diffuser Performance, Subsonic Cruise Inlet, supersonic inlets. Exhaust Nozzles- Efficiencies, Thrust reversal.

UNIT – III

06 Hours

Combustors and Afterburners:

Types of the combustion system, Operational requirements, some important factors affecting combustor design, the combustion process, Combustion chamber performance, Afterburners, and Gas turbine emissions. Thrust augmentation.

UNIT – IV

07 Hours

Compressors:

Compressor types: Introduction to centrifugal compressors, Axial flow compressor- geometry- twin spools- three spools- stage analysis- velocity polygons- degree of reaction – radial equilibrium theory- performance maps.

UNIT – V

07 Hours

Turbines:

Axial flow turbines: geometry- velocity polygons- stage analysis- performance map, thermal limit of blades and vanes, blade cooling.

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course, the student will be able to:		
1	Determine the performance characteristics of turboprop, turbojet and turbofan engines	L2 & L3
2	Calculate pressure and temperature changes across the propulsive device, inlet, and exhaust nozzle in a gas turbine engine from the knowledge of geometry.	L2 & L3
3	Compare different types of power plant installations in an aircraft.	L2 & L3
4	Outline the requirements of combustors and compare performance of different types of combustors.	L2 & L3
5	Determine the performance characteristics of centrifugal and axial flow compressors	L3 & L4
6	Determine the performance characteristics of axial flow turbines.	L3 & L4

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)												PSOs	
	1	2	3	4	5	6	7	8	9	10	11	12	1	2
C01	3	3	1	1	2								3	
C02	3	3	1		1								2	
C03	2	1											1	
C04	2						2						2	
C05	3	3	2	1									2	
C06	3	3	2	1									2	

3: Substantial (High)

2: Moderate (Medium)

1: Poor (Low)

TEXT BOOKS:

1. R. D. Flack, "Fundamentals of Jet Propulsion with Applications", Cambridge University Press, 2005
2. H. I. H. Saravanamuttoo, G.F.C. Rogers, H. Cohen, P.V. Straznicky, and A.C. Nix and, "Gas Turbine Theory", Pearson Education Limited, 7th edition, 2017

REFERENCE BOOKS:

1. S. Farokhi, "Aircraft Propulsion", John Wiley & Sons Ltd, 2nd edition, 2014.
2. Ahmed F. El-Sayed., "Aircraft Propulsion and Gas Turbine Engines,", CRC Press Taylor & Francis Group, 2nd Edition, 2017
3. Hill, P.G. and Peterson, C.R. "Mechanics and Thermodynamics of Propulsion", Pearson India, 2nd edition, 2009.
4. J. D. Mattingly, "Elements of Gas Turbine Propulsion", McGraw Hill Publications, 1996.
5. P. M. Sforza, "Theory of Aerospace Propulsion", Elsevier-BH, 2017

E-Resources:

1. <https://nptel.ac.in/courses/112103281>
2. <https://archive.nptel.ac.in/courses/101/101/101101002/>

SPACE FLIGHT MECHANICS

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – IV

Course Code :	23AS2404	Credits :	03
Hours / Week :	03 Hours	Total Hours :	39 Hours
L-T-P :	3-0-0		

Course Learning Objectives:

This course will enable students to:

1. Understand the basic concepts of space mechanics and the general N- body.
2. Study satellite injection and satellite orbit perturbations.
3. Acquire the knowledge of interplanetary and ballistic missile trajectories

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teachers can use to accelerate the attainment of the various course outcomes.

1. **Lecture method** means it includes not only traditional lecture method but different
2. *type of teaching methods* may be adopted to develop the course outcomes.
3. **Interactive Teaching: Adopt Active learning** that includes brainstorming, discussing, group work, focused listening, formulating questions, note taking, annotating, and roleplaying.
4. Show **Video/animation** films to explain the functioning of various concepts.
5. Encourage **Collaborative** (Group Learning) Learning in the class.
6. To make **Critical thinking**, ask at least three Higher-order Thinking questions in theclass.
7. Adopt **Problem Based Learning**, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
8. Show the **different ways to solve** the same problem and encourage the students to come up with their own creative ways to solve them.
9. Discuss how every **concept can be applied to the real world** - and when that's possible, it helps improve the student's understanding.

Course Content	
UNIT – I	8 Hours
Introduction of Space Flight Mechanics: Overview of major contents of universe, Introduction to space flight, Introduction to two-body problem, Equations of motion, Kepler's Laws, Conic sections, types of orbits, Conservation of energy and angular momentums, The three-body problem-Lagrange and Euler cases, The n-body problem.	
UNIT – II	08 Hours

Orbital elements: Coordinate systems- Geocentric right ascension-declination frame , Heliocentric and Geocentric equatorial system, Orbital elements and its determination from position and velocity vector, Effect of oblateness of Earth, Sidereal time, Topocentric coordinate system.	
UNIT – III	10 Hours
Orbital Maneuvers: In-plane orbit changes, Impulsive maneuvers, Hohmann transfer, Bi-elliptical transfer, plane change maneuvers. Interplanetary Trajectories: Intercept and Rendezvous, Relative motion in orbit, Two-dimensional interplanetary trajectories, concept of sphere of influence, Planetary departure, Planetary rendezvous, Planetary flyby.	
UNIT – IV	07 Hours
Satellite Injection and Satellite Perturbations: General aspects of satellite injection, satellite orbit transfer, various cases, orbit deviations due to injection errors, special and general perturbations, Cowell's method and Encke's method, method of variations of orbital elements, general perturbations approach.	
UNIT – V	06 Hours
Satellite Attitude Dynamics: Rigid body dynamics, Principal body axis frame, Parallel axis theorem, Euler's angles, The general torque-free rigid body, Attitude Control: Spinning and Nonspinning spacecrafts, Satellite Launch Vehicle Motion: Vertical motion in the earth's gravitational field, inclined motion, flight path at constant pitch angle, motion in the atmosphere, the gravity turn – the culmination altitude, multi staging.	

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course, the student will be able to:		
1	Apply the basic concepts of space mechanics and the general N-body.	L3&L4
2	Understand different coordinate systems, classify different types of orbits, properties of an orbit.	L3 & L4
3	Use space mechanics laws to summarize different orbital maneuvers.	L3 & L4
4	Distinguish between interplanetary and ballistic missile trajectories	L3 & L4
5	Discuss and compare Satellite launch vehicle trajectories and effect of gravity.	L3 & L4

COs	Program Outcomes (POs)												PSOs	
	1	2	3	4	5	6	7	8	9	10	11	12	1	2
C01	3	2	1		1							1	1	
C02	3	2			2								1	1
C03	3	2	1		1				1	1			1	1
C04	3	2	1		1				1	1				
C05	3	2	1											

3: Substantial (High) 2: Moderate (Medium) 1: Poor (Low)

Text Books:

1. William E. Wiesel , *Spaceflight Dynamics*, Aphelion Press (2010).
2. Howard Curtis, *Orbital Mechanics For Engineering Students*, Elsevier, 2005.

REFERENCE:

1. Van de Kamp, P., "Elements of Astromechanics", Pitman, 1979
2. Willian E. Wiesel, *Space Flight Dynamics*, Create Space Independent Publishing Platform, 3rd Edition ,2010,ISBN-13: 978-1452879598
3. George P. Sutton and Oscar Biblarz, *Rocket Propulsion Elements*, Wiley India Pvt Ltd, 7th edition, 2010, ISBN-13: 978-8126525775.

AEROSPACE MANUFACTURING			
[As per Choice Based Credit System (CBCS) scheme]			
SEMESTER – IV			
Subject Code : 23AS2405		Credits : 04	
Hours / Week : 03 Hours		Total Hours : 39 + 26 Hours	
L-T-P : 3-0-2			
Course Learning Objectives: This course will enable students to: 1. Analyze: Students should develop analytical thinking and problem-solving skills specific to aerospace manufacturing. They should be able to analyze complex manufacturing challenges, propose innovative solutions, and evaluate their feasibility and impact. 2. Get the idea: Students should understand the ethical and sustainability challenges in aerospace manufacturing and be aware of the importance of responsible manufacturing practices. 3. Devise: Students should be able to read and interpret aerospace engineering principles and be able to apply them in manufacturing processes. 4. Describe: Students should be able to explain the key concepts and principles that govern aerospace manufacturing processes, including materials selection, production methods, quality control, and safety considerations.			
Teaching-Learning Process (General Instructions) These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes. 1. Lecture method means it includes not only traditional lecture method, but different <i>type of teaching methods</i> may be adopted to develop the course outcomes. 2. Interactive Teaching: Adopt the Active learning that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying. 3. Show Video/animation films to explain functioning of various concepts. 4. Encourage Collaborative (Group Learning) Learning in the class. 5. To make Critical thinking , ask at least three Higher order Thinking questions in the class. 6. Adopt Problem Based Learning , which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it. 7. Show the different ways to solve the same problem and encourage the students to come up with their own creative ways to solve them. 8. Discuss how every concept can be applied to the real world - and when that's possible, it helps improve the students' understanding.			
UNIT – I			10 Hours
INTRODUCTION TO AEROSPACE MANUFACTURING Historical development of aerospace manufacturing, Current trends and future directions, Major players and stakeholders in the aerospace industry, Basic concepts of manufacturing, Traditional and advanced manufacturing techniques – casting, sheet metal working, forming, laser manufacturing. CNC machining technology.			
UNIT – II			08 Hours
ADDITIVE MANUFACTURING Fundamentals of Additive Manufacturing, AM Technologies and Processes, Multiple Materials, Additives, Powder Bed Fusion: Selective Laser Sintering (SLS), Direct Metal Laser Sintering (DMLS), Electron Beam Melting (EBM), Vat Photo polymerization; Stereo lithography (SLA), Digital Light Processing (DLP), Material Jetting and Binder Jetting, Sheet Lamination, Laminated Object Manufacturing (LOM), Ultrasonic Additive Manufacturing (UAM)			
UNIT – III			07 Hours

COMPOSITE MATERIALS PROCESSING

Carbon fibres: production, structure and properties, Glass fibres: production, structure and properties, Aramid (Kevlar) fibres: production, structure and properties, Dry fabrics and Core Materials, Epoxy, Phenolic resin, Polyimide, Prepreg Manual lay-up, Automated tape lay-up (ATL), Automated fibre placement (AFP), Resin infusion, Resin transfer moulding (RTM), Vacuum bag resin infusion (VBRI), Resin film infusion (RFI), Filament winding, Pultrusion, Machining of Composite, Metal matrix composites, fibre metal laminates composites, ceramic matrix composites, carbon-carbon composites.

UNIT – IV**07 Hours****SMART MANUFACTURING**

Digital Twin Technology, Introduction to digital twin, Applications in aerospace manufacturing, Benefits and challenges, Smart Manufacturing and Industry 4.0, IoT and its impact on aerospace manufacturing, Data analytics and predictive maintenance, Cyber-physical systems, Sustainable Manufacturing, Green manufacturing practices, Lifecycle assessment, Recycling and material recovery, Real-world case studies

UNIT – V**07 Hours****AEROSPACE MANUFACTURING PRINCIPLE AND STANDARDS**

Component manufacturing - Raw materials; Jet engine manufacturing process - fan blade, compressor disc, compressor blades, combustion chamber, turbine disc and blades, exhaust system and final assembly; Assembly line - Fundamentals of building Aircraft, Major aircraft materials and its classification, Composite materials and its manufacturing processes, Quality control and assurance.

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	Understand the historical development, current trends, and future advancements in aerospace manufacturing, and explain various traditional and advanced manufacturing techniques.	L2 & L3
2	Analyze different additive manufacturing processes such as Selective Laser Sintering (SLS), Direct Metal Laser Sintering (DMLS), and Electron Beam Melting (EBM), and evaluate their applications in aerospace components	L2 & L3
3	Apply composite materials processing techniques, including resin infusion, filament winding, and vacuum bag resin infusion, to develop aerospace structural components	L2 & L3
4	Apply smart manufacturing concepts such as Digital Twin, IoT, and Industry 4.0, and propose sustainable manufacturing strategies for aerospace production.	L2 & L3
5	Evaluate the material selection and production processes for jet engine components, and apply quality control standards in aircraft assembly.	L2

Table: Mapping Levels of COs to POs / PSOs														
COs	Program Outcomes (POs)												PSOs	
	1	2	3	4	5	6	7	8	9	10	11	12	1	2
CO1	3	3		2	3									
CO2	3	3	2	3	3									2
CO3	3	3		3	3	2	1							2
CO4	3	3	2	2	3	1	2							2
CO5	3	3			2	2	1							2
3: Substantial (High)				2: Moderate (Medium)				1: Poor (Low)						

TEXTBOOKS:

1. Kalpakjian, S. and Schmidt, S. R., Manufacturing Processes for Engineering Materials, 5th ed., Pearson Education (2007).
2. Pradip K. Saha., Aerospace Manufacturing Processes, CRC Press, Taylor & Francis Group, 2017
3. Gibson Rosen, Stucker, Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing. Springer, 2009.,

REFERENCE BOOKS:

1. Abbaschian, R., Abbaschian, L., and Reed-Hill, R. E., Physical Metallurgy Principles, 4th ed., Cengage Learning (2008).
2. Krishnadas Nair, C. G. and Srinivasan, R., Materials and Fabrication Technology for Satellite and Launch Vehicle, Navbharath Enterprises (2008)
3. Standard Handbook for Aerospace Engineers, Second Edition, By Brij N. Agrawal, Max F. Platzer · 2018
4. Engineering Materials: Polymers, Ceramics and Composites A.K Bhargava Prentice Hall India
5. Francis Froes, Rodney Boyer – Editors, Additive Manufacturing for the Aerospace Industry, Elsevier, 2019

E-Resources:

<https://archive.nptel.ac.in/courses/101/106/101106038/>

Activity-Based Learning (Suggested Activities in Class)

Group discussions on advanced manufacturing processes for aircraft component

Video demonstrations on advanced manufacturing techniques for spacecraft and group discussions

AEROSPACE MANUFACTURING LABORATORY

Total Contact Hours: 26

The following are physical experiments to be carried out

1. Development of composite material using hand lay-up & Vacuum Bag process.
2. Development of Honeycomb composite structures.
3. Design and development of fibre metal laminates
4. Injection moulding: To prepare a plastic product using injection moulding.
5. Development of fuselage structure using Filament winding process.
6. Tension & Flexural testing of composite materials.
7. Property Evaluation of composite materials (Tension/Flexural/Deflection)
8. Non Destructive testing of Aircraft structures (Ultrasonic Flaw detector)
9. 3D modelling and Development of aircraft structures using 3D printing.
10. Design and Development of emerging aero models using additive manufacturing.

INTRODUCTION TO COMPUTATIONAL FLUID DYNAMICS

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – IV

Subject Code	: 23AS2406	Credits	: 03
Hours / Week	: 04 Hours	Total Hours	: 13 + 26 Hours
L-T-P	: 1-0-2		

Course Learning Objectives:

This course will enable students to:

1. Explain the basic governing equations and understand the properties of CFD.
2. Understand discretization techniques and solving methods for improving accuracy.
3. Inculcate the knowledge required to solve physical problems using simulation software.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

1. **Lecture method** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
2. **Interactive Teaching: Adopt the Active learning** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
3. Show **Video/animation** films to explain functioning of various concepts.
4. Encourage **Collaborative** (Group Learning) Learning in the class.
5. To make **Critical thinking**, ask at least three Higher order Thinking questions in the class.
6. Adopt **Problem Based Learning**, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
7. Show the **different ways to solve** the same problem and encourage the students to come up with their own creative ways to solve them.
8. Discuss how every **concept can be applied to the real world** - and when that's possible, it helps improve the students' understanding.

UNIT – I	03 Hours
Introduction: Advantages and applications of CFD, CFD solution procedure – Pre-process, CFD solver, Post process, testing.	
UNIT – II	06 Hours
Governing Equations: Continuity, momentum and Energy equations, equations for turbulent flows, classification of PDEs, generic form of governing equations for CFD, physical boundary conditions	
UNIT – III	04 Hours
Mesh generation: Overview of mesh generation, Structured and Unstructured mesh, Guideline on mesh quality and design, Mesh refinement and adaptation, moving mesh.	
UNIT – IV	08 Hours
CFD Techniques: Discretization of governing equations – FDM, FVM, FEM, Numerical solution, Explicit and Implicit schemes, pressure velocity coupling.	
UNIT – V	05 Hours
CFD Solution Analysis:	

Consistency, stability, convergence, accuracy, efficiency. Guidelines for boundary conditions, turbulence modelling and Validation.

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course, the student will be able to:		
1	Outline the CFD solution procedure.	L2 & L3
2	Classify PDEs and derive governing equations- continuity, momentum and energy.	L2 & L3
3	Choose 2D grids for a particular fluid flow problem.	L2 & L3
4	Apply finite difference method and finite volume methods for the discretization of the fluid flow problems.	L2 & L3
5	Use of suitable numerical methods for solving the governing equations in the discretized domain by understanding stability and convergence.	L2 & L3
6	Solve fluid flow and heat transfer problems using CFD software	L2 & L3

Table: Mapping Levels of COs to POs / PSOs														
COs	Program Outcomes (POs)												PSOs	
	1	2	3	4	5	6	7	8	9	10	11	12	1	2
CO1	3				2								2	
CO2	3				2								1	
CO3	2	2			3							1	1	1
CO4	3	3	2		3									1
CO5	3	2	2		3									
CO6	3	2	2	2	3				2	2		2	2	2

3: Substantial (High)

2: Moderate (Medium)

1: Poor (Low)

TEXT BOOKS:

1. Jiyuan Tu, Guan-Heng Yeoh, Chaoqun Liu, "Computational Fluid Dynamics A Practical Approach", 3rd Edition, Butterworth-Heinemann, 2018.
2. Atul Sharma, "Introduction to Computational Fluid Dynamics Development, Application and Analysis", ANE Books Pvt. Ltd, Springer Nature Switzerland AG ,2022.

REFERENCE BOOKS:

1. H.K. Versteeg and W. Malalasekera , "An Introduction to Computational Fluid Dynamics: The Finite Volume Method" , , Second Edition, Pearson Education Limited, 2007.
2. Anderson J.D. Computational Fluid Dynamics, Mc-Graw Hills (1995)
3. J.C. Tannehill, D.A. Anderson, and R.H. Pletcher, Computational Fluid Mechanics and Heat Transfer, Taylor & Francis

E-Resources:

1. <https://nptel.ac.in/courses/112105045>

INTRODUCTION TO COMPUTATIONAL FLUID DYNAMICS - LAB

Total Contact Hours: 26

Following simulations to be done using CFD software:

1. Discretization and numerical solution of 1D steady-state heat transfer through the slab.
2. Numerical solution of a potential flow problem.
3. Solution convergence monitoring, flow visualization and post-processing techniques and tools.
4. Introduction to CFD software and setup test case-1 for laminar flow – internal and external.
5. Mesh generation for test case-1 using the inbuilt tool.
6. Grid independence test, results reporting and visualization.
7. CFD study of laminar and turbulent flow around a cylinder. Selection of different turbulent models.
8. CFD study of laminar flow past a backwards-facing step.
9. CFD study of natural convection in a square cavity.
10. CFD study of flow around airfoils.
11. CFD study of compressible flow around cylinders and cones.
12. CFD study of compressible flow around blunt bodies.
13. CFD study of flow behind a rotating cylinder.
