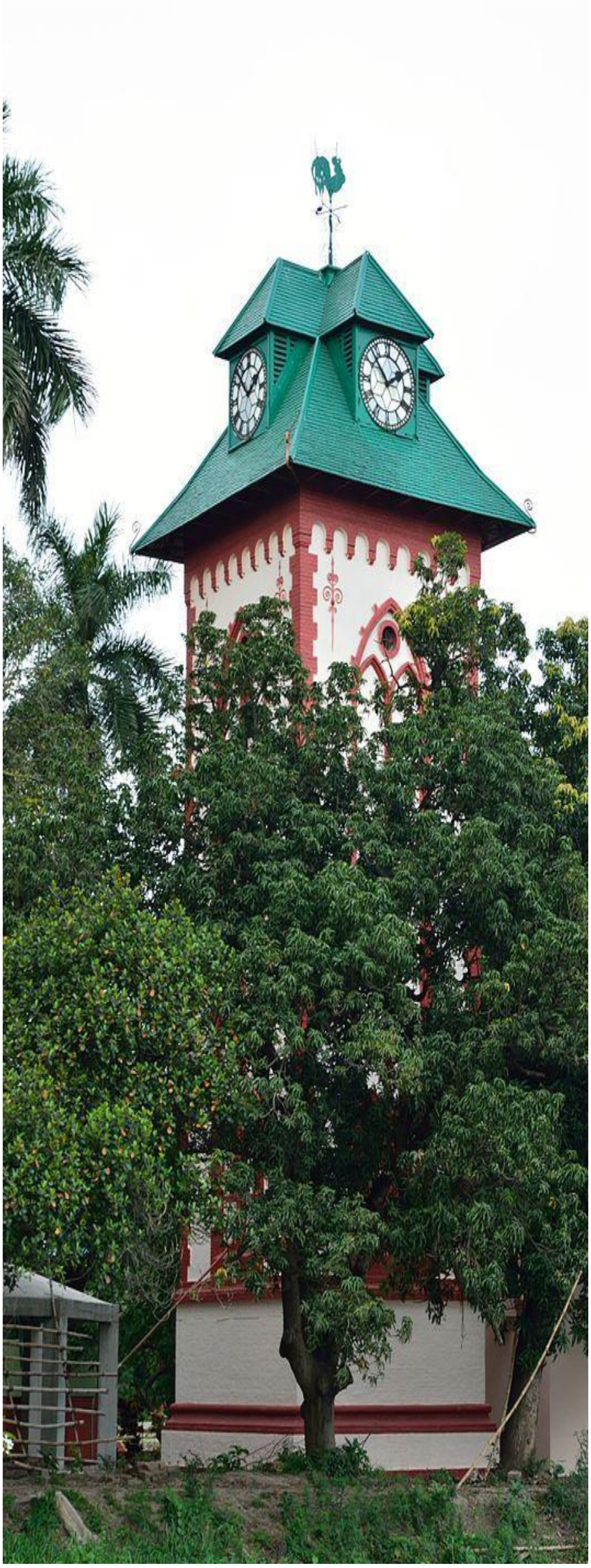

Aerospace Engineering and Applied Mechanics (for Group B)

B.Tech. Program
in
Aerospace Engineering

Course Structure and Syllabus

(Effective from 2025-26 admitting batch onwards)

Indian Institute of Engineering Science and Technology (IIEST), Shibpur

Botanic Garden, Howrah

Contents

Course Structure

First Semester									
Sl. No.	**Type**	**Course Name**	**Course code**	**Class Load/Week**			**Credit**	**Class load/ week**	**Marks**
				L	**T**	**P**			
1	BSC	Engineering Mathematics – I		3	1	0	4	4	100
2	BSC	Engineering Physics		3	0	0	3	3	100
3	ESC	Introduction to AI and ML		3	0	0	3	3	100
4	ESC	Engineering Mechanics	AM1101N	3	0	0	3	3	100
5	ESC	Basic Electrical Engineering		3	0	0	3	3	100
6	VAC	Energy, Environment, and Climate Change		2	0	0	2	2	50
		Theory Sub-total		**17**	**1**	**0**	**18**	**18**	**550**
7	ESC	Engineering Graphics	AM1171N	0	0	3	2	3	50
8	ESC	Computer Programming Practices		0	0	3	2	3	50
9	BSC	Physics Laboratory		0	0	3	2	3	50
10		NSS/NCC/PT/Yoga					R*		
		Practical Sub-total		**0**	**0**	**9**	**6**	**9**	**150**
		First Semester Total		**17**	**1**	**9**	**24**	**27**	**700**
*R: Required (Non-credit but with grade)									

Second Semester									
Sl. No	**Type**	**Course Name**	**Course code**	**Class Load/Week**			**Credit**	**Class load/ Week**	**Marks**
				L	**T**	**P**			
1	BSC	Engineering Mathematics – II		3	1	0	4	4	100
2	BSC	Engineering Chemistry		3	0	0	3	3	100
3	ESC	Engineering Thermodynamics	AM1204N	3	0	0	3	3	100
4	VAC	Well-being and happiness		2	0	0	2	2	50
5	HSC	Professional communication in English		2	1	0	3	3	100
6	PC	Introduction to Aerospace Engineering	AE1201N	3	0	0	3	3	100
		Theory Sub-total		**16**	**2**	**0**	**18**	**18**	**550**
7	ESC	Workshop		0	0	3	2	3	50
8	BSC	Chemistry Laboratory		0	0	3	2	3	50
9	ESC	Basic Electrical Engineering Laboratory		0	0	3	2	3	50
10	PC	Aeromodeling Laboratory	AE1271N	0	0	3	2	3	50
11		NSS/NCC/PT/Yoga					R*		
		Practical Sub-total		**0**	**0**	**12**	**8**	**12**	**200**
		Second Semester Total		**16**	**2**	**12**	**26**	**30**	**750**
*R: Required (Non-credit but with grade)									

Third Semester

Sl. No	Type	Course Name	Course	Class Load			Credit	Class load	Marks
				L	T	P			
1	ESC	Fluid Dynamics	AE2101N	3	0	0	3	3	100
2	ESC	Mechanics of Solids	AE2102N	3	0	0	3	3	100
3	PC	Numerical Methods and Computational Tools	AE2103N	3	0	0	3	3	100
4	PC	Rigid Body Dynamics	AM2102N	3	0	0	3	3	100
5	PC	Flight Mechanics	AE2104N	3	1	0	4	4	100
		Theory Sub-total		15	1	0	16	16	500
6	ESC	Strength of Materials Laboratory	AM2171N	0	0	3	2	3	50
7	ESC	Fluid Dynamics Laboratory	AE2171N	0	0	3	2	3	50
8	PC	Machine Drawing	AE2172N	0	0	3	2	3	50
9	PC	Numerical Methods and Computational Tools Laboratory	AE2173N	0	0	3	2	3	50
		Practical Sub-total		**0**	**0**	**12**	**8**	**12**	**200**
		Third Semester Total		**15**	**1**	**12**	**24**	**28**	**700**

Fourth Semester

Sl. No	Type	Course Name	Course Code	Class Load/Week			Credit	Class load/ week	Marks
				L	T	P			
1	PC	Aerodynamics I	AE2201N	3	0	0	3	3	100
2	PC	Aerospace Structure I	AE2202N	3	1	0	4	4	100
3	PC	Theory of Vibration	AE2203N	3	0	0	3	3	100
4	PC	Theory of Aircraft Propulsion	AE2204N	3	1	0	4	4	100
5	OE	OE1		3	0	0	3	3	100
		Theory Sub-total		15	2	0	17	17	500
6	PC	Computational Solid Mechanics Laboratory	AE2271N	0	0	3	2	3	50
7	PC	CAD Laboratory	AE2272N	0	0	3	2	3	50
8	PC	Vibration Laboratory	AE2273N	0	0	3	2	3	50
9	PC	Aerodynamics I Laboratory	AE2274N	0	0	3	2	3	50
		Practical Sub-total		**0**	**0**	**12**	**8**	**12**	**200**
		Fourth Semester Total		**15**	**2**	**12**	**25**	**29**	**700**

Fifth Semester									
Sl. No	**Type**	**Course Name**	**Course Code**	**Class Load/Week**			**Credit**	**Class load/ week**	**Marks**
				L	**T**	**P**			
1	PC	Aircraft Dynamics, Stability and Control	AE3101N	3	1	0	4	4	100
2	PC	Computational Fluid Dynamics	AE3102N	3	0	0	3	3	100
3	PC	Introduction to FEM and Applications	AE3103N	3	0	0	3	3	100
4	PC	Composites and Structures	AE3104N	3	0	0	3	3	100
5	OE	OE2		3	0	0	3	3	100
		Theory Sub-total		**15**	**1**	**0**	**16**	**16**	**500**
6	PC	Aircraft Dynamics, Stability and Control Laboratory	AE3171N	0	0	3	2	3	50
7	PC	Mathematical Modeling and Simulation Laboratory	AE3172N	0	0	3	2	3	50
8	PC	Propulsion Laboratory	AE3173N	0	0	3	2	3	50
9	PC	Computational Fluid Dynamics Laboratory	AE3174N	0	0	3	2	3	50
		Practical Sub-total		**0**	**0**	**12**	**8**	**12**	**200**
		Fifth Semester Total		**15**	**1**	**12**	**24**	**28**	**700**

Sixth Semester									
Sl. No	**Type**	**Course Name**	**Course Code**	**Class Load/Week**			**Credit**	**Class load/ week**	**Marks**
				L	**T**	**P**			
1	PC	Aerodynamics II	AE3201N	3	0	0	3	3	100
2	PC	Jet and Rocket Propulsion	AE3202N	3	0	0	3	3	100
3	PC	Aerospace Structure II	AE3203N	3	0	0	3	3	100
4	HSC	Finance Economics and Management for Engineers		3	0	0	3	3	100
5	OE	OE3		3	0	0	3	3	100
		Theory Sub-total		**15**	**0**	**0**	**15**	**15**	**500**
6	PC	Aerodynamics II Laboratory	AE3271N	0	0	3	2	3	50
7	PC	Aerospace Structures Laboratory	AE3272N	0	0	3	2	3	50
8	PC	Aircraft Design and Flight Training	AE3273N	0	0	3	2	3	50
		Practical Sub-total		**0**	**0**	**9**	**6**	**9**	**150**
		Sixth Semester Total		**15**	**0**	**9**	**21**	**24**	**650**

Seventh Semester									
Sl. No	**Type**	**Course Name**	**Course Code**	**Class Load/Week**			**Credit**	**Class load/ week**	**Marks**
				L	**T**	**P**			
1	PC	Turbulence	AE4101N	3	0	0	3	3	100
2	PSE	Aerospace Structural Dynamics/Orbital Mechanics	AE4121N/ AE4122N	3	0	0	3	3	100
3	VAC	Sociology & Professional Ethics		3	0	0	3	3	100
4	OE	OE4		3	0	0	3	3	100
		Theory Sub-total		**12**	**0**	**0**	**12**	**12**	**400**
5	PC	Flow Visualization Laboratory	AE4171N	0	0	3	2	3	50
6	PC	Advanced Design Project	AE4191N	0	0	3	2	3	50
7	I	Internship	AE4192N				2		50
		Practical Sub-total		**0**	**0**	**6**	**6**	**6**	**150**
		Seventh Semester Total		**12**	**0**	**6**	**18**	**18**	**550**

Eighth Semester									
Sl. No	**Type**	**Course Name**	**Course Code**	**Class Load/Week**			**Credit**	**Class load / week**	**Marks**
				L	**T**	**P**			
1	OE	OE5 (from NPTEL for the students opting Internship/ for others from Institute)		3	0	0	3	3	100
		Theory Sub-total		**3**	**0**	**0**	**3**	**3**	**100**
2	I/P	One Semester Internship / Project	AE4291N				8		300
3	O	Grand viva	AE4292N				2		50
		Practical Sub-total		**0**	**0**	**0**	**10**	**0**	**350**
		Eighth Semester Total		**3**	**0**	**0**	**13**	**3**	**450**

Catalogue of Courses

Catalogue of Engineering Science Courses

Sl. No.	Course Code	Course Name
1	AM1101N	Engineering Mechanics
2	AM1171N	Engineering Graphics
3	AM1204N	Engineering Thermodynamics
4	AE2101N	Fluid Dynamics
5	AE2102N	Mechanics of Solids
6	AM2171N	Strength of Materials Laboratory
7	AE2171N	Fluid Dynamics Laboratory

Catalogue of Basic Science Courses

Sl. No.	Course Code	Course Name
1		
2		
3		
4		
5		

Catalogue of Humanities and Social Science Courses

Sl. No.	Course Code	Course Name
1		
2		
3		
4		
5		

Catalogue of Value Added Courses

Sl. No.	Course Code	Course Name
1		
2		
3		
4		

Catalogue of Program Core Courses

Sl. No.	Course Code	Course Name
1	AE1201N	Introduction to Aerospace Engineering
2	AE1271N	Aeromodeling Lab
3	AE2103N	Numerical Method and Computational Tools
4	AM2102N	Rigid Body Dynamics
5	AE2104N	Flight Mechanics
6	AE2172N	Machine Drawing
7	AE2173N	Numerical Method and Computational Tools Laboratory
8	AE2201N	Aerodynamics I
9	AE2202N	Aerospace Structure I
10	AE2203N	Theory of Vibration
11	AE2204N	Theory of Aircraft Propulsion
12	AE2271N	Computational Solid Mechanics Laboratory
13	AE2272N	CAD Laboratory
14	AE2273N	Vibration Laboratory
15	AE2274N	Aerodynamics I Laboratory
16	AE3101N	Aircraft Dynamics, Stability and Control
17	AE3102N	Computational Fluid Dynamics
18	AE3103N	Introduction to FEM and Applications
19	AE3104N	Composites and Structures
20	AE3171N	Aircraft Dynamics, Stability and Control Laboratory
22	AE3172N	Mathematical Modeling and Simulation Laboratory
23	AE3173N	Propulsion Laboratory
24	AE3174N	Computational Fluid Dynamics Laboratory
25	AE3201N	Aerodynamics II

26	AE3202N	Jet and Rocket Propulsion
27	AE3203N	Aerospace Structure II
28	AE3271N	Aerodynamics II Laboratory
29	AE3272N	Aerospace Structures Laboratory
30	AE3273N	Aircraft Design and Flight Training
31	AE4101N	Turbulence
32	AE4171N	Flow Visualization Laboratory
33	AE4194N	Advanced Design Project

Catalogue of Program Specific Elective Courses

Sl. No.	Course Code	Course Name
1	AE4121N	Aerospace Structural Dynamics
2	AE4122N	Orbital Mechanics

Catalogue of Open Elective Courses

Sl. No.	Course Code	Course Name
1	AM2261M	Viscous Flow
2	AM3161N	Droplets and sprays
3	AM3162N	Materials Selection and Manufacturing Process
4	AM3163N	Avionics and Navigation
5	AM3164N	Mechatronics
6	AM3261N	Industrial Combustion
7	AM3262N	Experimental Stress Analysis
8	AM3263N	Parallel Computation
9	AM3264N	Micro and Nano-scale Transport Processes
10	AM3265N	Fracture Mechanics
11	AM3266N	Finite Element Method
12	AM3267N	Design Thinking
13	AM4161N	Fundamentals of Combustion
14	AM4162N	Convective heat and mass transfer
15	AM4163N	Industrial Hydraulics and Pneumatics
16	AM4164N	Rotorcraft Dynamics

Syllabi of Courses

Detailed Syllabus

1st Semester Courses Syllabi

B. Tech in Aerospace Engineering

Course Code	AM1101N	Course Name	Engineering Mechanics	Course Category	ESC	L	T	P
						3	0	0

Pre-requisite Courses	Nil	Co-requisite Courses	Nil	Progressive Courses	Mechanics of Solids and Fluids
Course Offering Department		Aerospace Engineering and Applied Mechanics		Data Book / Codes/Standards	Nil

Course Objectives	
	• To develop the ability to analyze and solve engineering problems involving forces and motion by understanding the fundamental concepts of statics and dynamics. • Analyze the behavior of rigid bodies and particles under static and dynamic loads respectively, including techniques like free body diagrams, equilibrium equations, and kinematic analysis. • Laying the groundwork for more advanced subjects such as strength of materials, fluid mechanics, and mechanical design.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	**Introduction to Statics:** Mechanics; Basic Concepts; Scalars and Vectors; Newton's Law	01	By the end of this module, students will be able to: • **Understand fundamental concepts of mechanics** i.e., distinction between statics and dynamics and also differentiate between scalar and vector quantities in solving mechanics problems.
II	**Force Systems:** Force Systems in Two Dimensions; Moments and Couples;	02	By the end of this module, students will be able to: • Classify different types of force systems, including concurrent, parallel, coplanar, non-coplanar, and general force systems. • Determine the resultant of a force system, including both magnitude and direction, and locate the point of application using moment and couple analysis.
III	**Equilibrium:** Free Body Diagram, Conditions for Equilibrium in Two Dimensional	03	By the end of this module, students will be able to: • Determine unknown forces and moments in beams, trusses, and frames using equilibrium principles. • Evaluate stability and determinacy of two-dimensional structures.

IV	**Structures:** Plane Trusses and Frames	05	By the end of this module, students will be able to: • Apply the method of joints and method of sections to determine member forces in statically determinate trusses.
V	**Distributed Force Systems:** Center of Mass; Centroid of Lines; Areas and Volumes; Theorems of Pappus; Area Moments of Inertia	07	By the end of this module, students will be able to: • Calculate the **resultant force and Area moment of Inertia** of distributed loads and locate the **center of gravity** or **point of application.**
VI	**Friction:** Friction – Application to wedges	06	By the end of this module, students will be able to: • Analyze Equilibrium Involving Frictional Forces, • Apply Friction Principles to Wedge Problems.
VII	**Kinematics of Particles:** Two Dimensional Particle Kinematics in Rectangular Coordinates, Cylindrical Co-ordinates and in terms of Normal and Tangential Components.	09	By the end of this module, students will be able to: • Solve problems involving projectile motion and general 2D kinematics in rectangular coordinates.
VIII	**Kinetics of Particles:** Conservation Laws – Approaches in terms of Force, Mass and Acceleration; Work and Energy; Linear Impulse and Momentum – Impact; Angular Impulse and Momentum – Central Force Motion;	09	By the end of this module, students will be able to: • Apply the work-energy theorem to solve problems involving conservative and non-conservative forces. • Analyze systems under impulsive loading, including sudden forces and collisions.

Course Outcome	At the end of the course, the student will be able to: • Obtain the equivalent force – couple system of a given system • Analyze the equilibrium state of a particle and rigid body • Estimate the moment of inertia of composite area about centroidal or any arbitrary axis • Determine the velocity and acceleration of a particle in rectangular and cylindrical coordinate systems of rigid bodies in general plane motion.

Learning Resources	**Text Book:** • Engineering Mechanics Statics (Vol. I) and Dynamics (Vol. II) – J.L. Meriam & L.G. Kraige **Reference Books:** • Engineering Mechanics Statics and Dynamics – I.H. Shames • Vector Mechanics for Engineers Statics – F.P. Beer and E.R. Johnston Jr. • Vector Mechanics for Engineers Dynamics – F.P. Beer and E.R. Johnston Jr.

Course Code	AM1171N	Course Name	Engineering Graphics	Course Category	ESC	L	T	P
						3	0	0

Pre-requisite Courses	Nil	Co-requisite Courses	Nil	Progressive Courses	Machine Drawing
Course Offering Department		Aerospace Engineering and Applied Mechanics		Data Book / Codes/Standards	Nil

Course Objectives	
	• To introduce students to the fundamentals of engineering drawing and visualization, enabling them to effectively communicate technical information through graphical representation using manual and computer-aided drafting tools. • Introduce the principles of orthographic projection, isometric views, sectional views, and dimensioning.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	**Introduction to Engg. Drawing:** Geometric Constructions, Types of Lines, Symbols, Hatchings, Dimensioning Styles, and Copy Figure	02	By the end of this module, students will be able to: • Construct standard geometric shapes using drawing instruments (e.g., bisecting angles, drawing tangents, polygons, etc.).
II	**Projection of Points, Lines & Surfaces:** Concept of Projection Planes and Corresponding Methods, Concept of True Length and True Angles, Plan and Elevation Lengths and Angles only in First angle Projection, Projection of Plane Surfaces with regular Geometric Boundaries	08	By the end of this module, students will be able to: • Differentiate between various projection planes (Horizontal Plane, Vertical Plane) • Generate and analyze **top view (plan), front view (elevation)** and side view of points and lines in various spatial positions.
III	**Projection of Solids:** Projection of Regular Solids resting on H.P. on corners, sides, and bases.	08	By the end of this module, students will be able to: • Draw accurate projections (front view and top view) of regular solids resting on H.P. on their base, side, corner and angle with VP.
IV	**Section of Solids:** Sectional Views of Regular Solids, Concept of True Shapes	06	By the end of this module, students will be able to: • Generate accurate sectional front and top views of regular solids (prisms, pyramids, cylinders, cones, etc.) cut by various types of planes.
V	**Orthographic Projection:** Conversion of Pictorial Views to Two-Dimensional Views on Planes of Projections	07	By the end of this module, students will be able to:

			• Draw accurate two-dimensional views (front, top, side) from given pictorial sketches.
VI	**Isometric Projection:** Concept of Isometric Scales, Isometric View, and Isometric Projection	08	By the end of this module, students will be able to: • Draw isometric projection/view along isometric axes.
VII	**End Test**	03	• Evaluating the Performance

Course Outcome	At the end of the course, the student will be able to: • Interpret and create 2D and 3D engineering drawings. • Use standard drawing conventions and scales effectively. • Apply geometric constructions, orthographic projections, and isometric views. • Communicate design ideas clearly through graphical methods.

Learning Resources	**Reference Books:** • Engineering Drawing by N. D. Bhatt • Engineering Drawing And Graphics by K. Venugopal

2nd Semester Courses Syllabi

B. Tech in Aerospace Engineering

Course Code	AM1204N	Course Name	Engineering Thermodynamics	Course Category	ESC	L	T	P
						3	0	0

Pre-requisite Courses	• Engineering Physics • Engineering Mathematics-I (Calculus and Linear Algebra)	Co-requisite Courses	• Workshop / Engineering Graphics • Engineering Mathematics -II	Progressive Courses	• Heat Transfer • Fluid Mechanics • Aircraft Propulsion • Combustion • Gas Dynamics • Turbomachinery
Course Offering Department		Aerospace Engineering and Applied Mechanics		Data Book / Codes/Standards	• Thermodynamic Property Tables (Steam, Air, Refrigerants) • Ideal Gas Tables and Compressibility Charts

Course Objectives	To introduce the fundamental principles of classical thermodynamics and their engineering applications. The course aims to equip students with the analytical tools necessary to understand energy conversion, work and heat interactions, and the formulation and application of the first and second laws of thermodynamics in aerospace and mechanical systems.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	**Introduction to classical thermodynamics**: Energy conversion, Internal energy, Microscopic vs. Macroscopic viewpoint; Thermodynamic system and control volume, Properties and State of a substance, Processes and Cycles; Thermodynamic equilibrium, The Zeroth law of thermodynamics; Quasi equilibrium process	04	• Describe the foundational principles of thermodynamic systems, control volumes, state postulates, and energy interactions including internal energy and process paths. • Analyze thermodynamic equilibrium and quasi-equilibrium processes, and apply the Zeroth Law to define the thermodynamic temperature scale within macroscopic and microscopic frameworks.
II	**Work and Heat interactions**: Work, Simple compressible system, Work done at a moving boundary; Other modes of work transfer; Heat, Comparison of heat and work	04	• Formulate expressions for different modes of work and heat transfer in simple compressible systems, including boundary work. • Interpret the thermodynamic significance of work and heat interactions and differentiate their roles in energy exchange processes.
III	**First law of thermodynamics**: 1st law for a Cycle, 1st law for a control mass, Internal energy – a thermodynamic property, Enthalpy, Specific heats; 1st law for a control volume – the steady-state steady-flow (SSSF) model, the transient flow model, and their applications	07	• Apply the first law of thermodynamics to closed and open systems, including cyclic and non-cyclic processes. • Evaluate energy conservation using internal energy, enthalpy, and specific heats in steady-state steady-flow (SSSF) and transient flow conditions.
IV	**Second law of thermodynamics**: Limitations of 1st law, Statements of 2nd	12	• Explain the second law of thermodynamics, including its

	law of thermodynamics, 1st law (thermal) efficiency and C.O.P; Reversible and irreversible processes; The Carnot cycle; Thermodynamic temperature scale; Inequality of Clausius, Entropy – a thermodynamic property, 2nd law equation for a control mass, Principle of the increase of entropy; Thermodynamic property relations, Reversible polytropic processes for an ideal gas; 2nd law equation for a control volume - The steady-state steady-flow (SSSF) model, the transient flow model; Thermal efficiencies of nozzle, turbine and compressor		statements, limitations of the first law, and reversible vs. irreversible processes. • Apply second law principles to analyze entropy changes, the Carnot cycle, and thermal efficiencies for control masses and control volumes. • Evaluate the thermal performance of nozzles, turbines, and compressors using entropy and polytropic process concepts.
V	**Irreversibility and Availability**: Reversible work, Evaluating irreversibility in a general transport process, Availability or Exergy, Exergy balance for a closed system, Exergy balance for control volumes at steady state, 2nd law efficiency, The Maxwell relations; Behaviour of real gases	06	• Understand irreversibility and exergy concepts, including evaluation of irreversibility and exergy balances for closed and open systems. • Apply second law efficiency and Maxwell relations to analyze real gas behavior and thermodynamic processes.
VI	**Power cycles**: Rankine cycle; Brayton cycle, regenerator, Air standard cycle for jet propulsion; Working principle of Spark-ignition and Compression-ignition engines, Otto cycle, Diesel cycle	06	• Describe Rankine, Brayton, and jet propulsion cycles. • Explain spark-ignition and compression-ignition engines with Otto and Diesel cycles.
VII	**Combustion thermodynamics**: Mixture of ideal gases, fugacity; Fuels, Combustion process, Enthalpy of formation, First-law analysis of reacting systems, Adiabatic flame temperature, Higher and lower heating value; Third law of thermodynamics	03	• Understand combustion fundamentals, including fuel properties, reacting mixtures, and enthalpy of formation. • Apply first law to reacting systems and analyze adiabatic flame temperature and heating values.

Course Outcome	Upon successful completion of this course, the students will be able to: 1. Define and explain basic thermodynamic properties and concepts including system, control volume, state, process, and cycle. 2. Interpret and use thermodynamic property tables and equations of state for pure substances. 3. Analyze work and heat interactions in thermodynamic systems. 4. Apply the first law of thermodynamics to closed and open systems. 5. Understand and apply the second law of thermodynamics, including the concepts of entropy and exergy. 6. Evaluate the performance of thermodynamic cycles used in power generation and propulsion systems. 7. Analyze chemical reactions and combustion processes from a thermodynamic perspective.

Learning Resources	**Textbooks:** • Thermodynamics: An Engineering Approach by Yunus A. Cengel and Michael A. Boles, McGraw Hill • Fundamentals of Engineering Thermodynamics by Moran, Shapiro, Boettner, and Bailey, Wiley **Reference Books:** • Engineering Thermodynamics by P.K. Nag, McGraw Hill Thermodynamics by J.P. Holman, McGraw Hill • Classical and Statistical Thermodynamics by Ashley H. Carter, Pearson **Data Book:** Thermodynamic Tables and Charts (available with standard textbooks or department resource)

Course Code	AE1201N	Course Name	Introduction to Aerospace Engineering	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	Elementary mechanics	Co-requisite Courses	Aerodynamics, propulsion, and Aircraft structures	Progressive Courses	High-speed aerodynamics, Aircraft dynamics and control
Course Offering Department		Aerospace Engineering and Applied Mechanics		Data Book / Codes/Standards	See learning Resources

Course Objective	
	• Introduce the fundamental concepts and history of aerospace engineering. • Provide an overview of aircraft and spacecraft systems. • Familiarize students with basic aerodynamics, propulsion, structures, materials, and flight mechanics. • Develop an understanding of the current trends and career paths in aerospace.

Module	Syllabus	Classes	Outcome
1	History of flight Contributions of Otto Lilienthal-Pioneering glider experiments; empirical data on lift and control, Hiram maxim-Steam-powered aircraft tests; contributions to aircraft control, Samuel Pierpont Langley- Aerodrome models and manned flight attempts and Wright brothers- First sustained, controlled, powered flight (1903)	5	Understand the evolution of flight through key contributions by early aviation pioneers.
2	Introduction to Helicopters: Rotor hub, swash plate, Cyclic control, collective control, Function of tail rotor, Types of helicopter: coaxial, intermeshing, tandem. Autorotation	6	Learn helicopter configurations, rotor mechanics, and basic flight principles including autorotation.
3	Fundamentals of Aerodynamics- Atmosphere & ISA model - Airfoil terminology Physical understanding of Lift and drag, Incorrect theories of lift, Lift and drag equation, Factors affecting lift and drag, L/D ratio, Inclination and downwash effect of lift	8	Grasp lift and drag principles, airfoil behavior, and atmospheric models affecting flight.
4	Propulsion Systems- Basics of thrust and impulse - Aircraft engines: piston, turbojet, turbofan, Vectored thrust, T/W ratio - Rocket engines: solid, liquid - Electric propulsion	6	Understand thrust generation and compare various aircraft and rocket propulsion systems.
5	Aircraft Structures and Materials- Aircraft structural elements - Aerospace materials: aluminium, titanium, composites , Load factor, Flight envelope, Flight stresses	7	Identify aircraft structural components, material properties, and understand load factors and stress limits.

6	Flight Mechanics and Performance- Flight forces: lift, drag, thrust, weight. Powered flight and gliding flight, Flight phases - Stability and control: parts of airplane: rudder, aileron, flaps, slats, flaperon, spoileron, Performance: range, endurance	6	Analyze flight forces, phases, control surfaces, and performance metrics like range and endurance.
7	Emerging Technologies and Future of Aerospace- UAVs, drones, VTOL, Reusable rockets	4	Explore advancements in aerospace, including UAVs, VTOLs, and reusable space technologies.

Course Outcome	By the end of the course, students will understand the history of flight, helicopter flight principles, and basic aerodynamics. They will identify key propulsion systems, aircraft structures, and apply flight mechanics to assess performance and stability. Students will also explore emerging aerospace technologies like UAVs, VTOLs, reusable launch systems, and green aviation.

Learning Resources	**Textbooks:** 1. Introduction to Flight – John D. Anderson Jr. 2. Fundamentals of Aerospace Engineering – Manuel Soler **Reference Books:** **1.** Aerospace Engineering: From the Ground Up – Ben Senson 2. Aircraft Structures for Engineering Students – T.H.G. Megson Online: https://www1.grc.nasa.gov/beginners-guide-to-aeronautics/learn-about-aerodynamics/

Course Code	AE1271N	Course Name	Aeromodelling lab	Course Category	PC	L	T	P
						0	0	3

Pre-requisite Courses	Elementary mechanics,	Co-requisite Courses	Aerodynamics, propulsion, and Aircraft structures	Progressive Courses	Advanced aircraft design, Unmanned Aerial Vehicles
Course Offering Department		Aerospace Engineering and Applied Mechanics		Data Book / Codes/Standards	See learning Resources

Course Objective	This course introduces students to the fundamentals of aeromodelling through the design, fabrication (manufacturing), and testing of flying models. It builds practical skills in flight principles, control systems, and model construction using tools like foam cutting, 3D printing, and CNC machining. Through hands-on projects, students develop technical proficiency, creativity, teamwork, and familiarity with digital manufacturing techniques.

Module	Syllabus	Classes	Outcome
1	**Introduction to Aeromodelling** – Types of Models, Tools, Materials, Safety Guidelines, Basic Principles of Flight – Forces on Aircraft, Control Surfaces, Servo, receiver, battery, motor, ESC, propeller. Demonstration of a Radio controlled aircraft. (Activity: Charging a LiPo battery with appropriate settings)	5	Understand aeromodelling basics, aircraft components, flight principles, and safety practices through demonstrations.
2	**Making a simple glider using stationary materials like paper, thermocol, glue, tape etc. and estimate its performance.** (Activity: Measurement of Range, Glide slope and glide angle. Understanding of control surfaces. Effect of center of gravity and trim, aspect ratio, elevator angle on glide slope).	6	Construct simple gliders and evaluate performance parameters like glide angle, trim, CG, and control surface effects.
3	**Computer Aided Manufacturing (CAM)**: CNC Technology and APT Programming, Industrial Automation, Intelligent Manufacturing, Industry 4.0 and 5.0, Non-traditional Machining, Demonstration of CNC machines, Automation Production System.	8	Gain foundational knowledge of CNC machining, automation, and modern manufacturing technologies.
4	**Manufacturing techniques**: Make a simple HOT wire foam cutter, Introduction to use GRBL hotwire CNC for cutting wings (Activity: Generate G code for cutting a wing for a given airfoil)	3	Design and generate G-code to cut airfoil wings using a GRBL-based hot wire CNC foam cutter.

5	**Introduction to 3D printing and CNC laser cutting:** FDM, Resin, print settings, precautions, optimizations to reduce time, printing supports, overhangs, (Activity: Generate a G-CODE for 3D printing a given part or cutting a profile using CNC Laser cutting machine.)	5	Learn G-code generation, printing techniques, and machine settings for efficient 3D printing and laser cutting.
6	**Group project:** Making a RC aeromodel: Manufacturing wings, tail, control surface, motor mount, landing gear, Mounting servo motors, propellers, ESC, battery and CG adjustment.	6	Integrate and assemble RC aircraft systems, including structure, electronics, and CG balancing.
7	**Flight simulator practice**, Introduction to FPV racing Stabilize, GPS hold and ACRO modes	6	Practice flying using simulators and explore FPV racing modes and flight controller functionalities.
8	**Evaluation and make up classes.** (Students will have to prepare a presentation and submit report for evaluation)	3	Present project work and submit reports for final evaluation and course consolidation.

Course Outcome	By the end of the course, students will be able to: • Identify types of aeromodels, components, tools, and safety practices. • Apply flight principles to build and test gliders, assessing range, glide slope, and stability. • Use hot wire cutting and generate G-code for CNC foam wing cutting. • Operate 3D printers and CNC tools for making aeromodel parts. • Collaboratively design and assemble an RC aircraft with proper propulsion, control, and CG setup.

Learning Resources	http://rc-plans.com/catalog/item401.html https://rckeith.co.uk/ https://oscarliang.com/lipo-battery-guide/ https://lasergrbl.com/download/ https://m-selig.ae.illinois.edu/props/propDB.html http://airfoiltools.com/search/index Free flight simulator: https://rowlhouse.co.uk/PicaSim/download.html

3rd Semester Courses Syllabi

B. Tech in Aerospace Engineering

Course Code	AE2101N	Course Name	Fluid Dynamics	Course Category	ESC	L	T	P
						3	0	0

Pre-requisite Courses	Mathematics (ODE, PDE, vector calculus)	Co-requisite Courses	Nil	Progressive Courses	Aerodynamics, Viscous flow, Propulsion
Course Offering Department		Aerospace Engineering & Applied Mechanics		Data Book / Codes/Standards	Nil

Course Objectives	• To provide students with a fundamental understanding of the governing equations of fluid motion, CV-based and differential approach of solving problems, potential flow, boundary layer, and incompressible internal flow. • Form a strong foundation that will help students in studying other specialized courses such as Aerodynamics, Propulsion and CFD

Module	Syllabus	Duration (class-hour)	Module Outcome
I	**Introduction**: Distinction between solids & fluids, fluid as a Continuum; Description of motion; Fluid properties, dimensions and units; Flow visualization; Classification of fluid flow	7	• Understand different approaches of describing fluid motion, • Understand the physical significance of viscosity and compressibility, • Describe various approaches to visualize fluid motion
II	**Pressure Distribution in a Fluid:** Equilibrium of a fluid element, Hydrostatic pressure in atmosphere, Manometry, forces on submerged surfaces	3	• Formulate the equations of hydrostatics and dynamic equilibrium, • Learn the techniques of pressure measurement
III	**Reynolds transport theorem**: Integral form of mass and momentum (linear) conservation equations, mechanical energy balance at steady state: Euler's equation along a streamline and Bernoulli's equation, Idealized theory of propeller	7	• Formulate general transport equation (RTE), • Analyse steady flow problems involving pipe bend, nozzle, propeller, impact of jet, etc.
IV	**Differential equations of fluid motion:** Continuity equation, stream function, general motion of a fluid element, strain rate, vorticity, dilatation, stress at a point, mechanical pressure, Navier-Stokes equation and its application - Couette flow and Poiseuille flow	9	• Formulate relationships between derived variables (*e.g.*, vorticity and strain rate) and primitive variables (*e.g.* velocity and pressure) characterising fluid flow,

			• Understand the physical significance of stream function, dilatation, etc. • Deduce continuity and Navier-Stokes equation, and apply them to simple geometries (*e.g.*, channel)
V	**Potential flow**: Velocity potential, elementary potential flow patterns, Principle of super-position - flow past a Rankine half body, Bernoulli's equation for potential flow	4	• Understand the physical significance of velocity potential, • Formulate the governing equations for irrotational flow, • Superimpose basic potential flow patterns to obtain more complex flow field
VI	**Introduction to Boundary layer**: Prandtl's approximation, measures of boundary layer thickness, elementary results for flat plates	5	• Perform boundary layer calculations (*e.g.*, various thicknesses and drag) on a flat surface
VII	**Flow through pipe**s: Hagen-Poiseuille equation, Head loss, kinetic energy correction factor; Darcy's equation for fully developed pipe flow, Moody chart, minor loss	5	• Understand the role of Reynolds number on the flow and pressure drop, • Calculate head loss, pipe size and flow rate for pipe flow
VIII	**Flow measurements:** Application of Bernoulli principle – Pitot tube and Pitot-static tube, orifice meter, venturi-meter	2	• Learn various methods of velocity and flow rate measurements

Course Outcome	On successful completion of this course, students should be able to: • learn the fundamentals concepts of Fluid dynamics (e.g., Reynolds transport theorem, flow kinematics, steam function, Navier-Stokes equation, Euler's equation and potential flow theory, boundary layer, pipe flow and head loss) • analyze and solve engineering problems, using the analytical tools introduced though the course • learn about the real-life applications of the theory

Learning Resources	1. F M White, *Fluid Mechanics*, McGraw-Hill International 2. R W Fox and A T McDonald, *Introduction to Fluid Mechanics*, Wiley India 3. Bernerd Massey, *Mechanics of Fluids*, Taylor & Francis

Course Code	AE2102N	Course Name	Mechanics of Solids	Course Category	ESC	L	T	P
						3	0	0

Pre-requisite Courses	Nil	Co-requisite Courses	Nil	Progressive Courses	Aircraft Structure I
Course Offering Department		Aerospace Engineering and Applied Mechanics		Data Book / Codes/Standards	None

Course Objective	The objective of this course is to provide Aerospace Engineering students with a fundamental understanding of how the deformable bodies respond to tension, compression, bending, torsion etc. types of mechanical loading and also due to thermal loading. The course aims to equip students with the analytical skills necessary to determine stresses, strains, and deformations in the structures. It also emphasizes the application of theoretical concepts for safe and efficient design of structures such as beams, shafts, columns and thin-walled members. Through this course, students will develop a strong foundation for advanced studies in mechanical and aerospace structures and materials.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	Introduction and concept of stress, strain, normal and shear stress, stress-strain diagrams of ductile and brittle materials, Hooke's law, elastic constants, Poisson's ratio, pure shear, shear modulus, bulk modulus, strain energy in tension and compression, and thermal stress	04	Understand and apply fundamental concepts of stress, strain, elastic constants, stress-strain behavior, strain energy, and thermal stresses in materials.
II	Bi-axial tension and compression, Mohr's circle for biaxial stress, pure shear, thin-walled pressure vessels, analysis of plane stress, principal stresses in beams, analysis of plane strain, principal strains, Mohr's circle for stress and strain	06	Analyze and interpret biaxial stress and strain conditions using Mohr's circle, including applications to thin-walled pressure vessels, plane stress and strain, and principal stresses and strains.
III	Torsion of circular shaft, torsional stress, modulus of rigidity, strain energy in shear and torsion	04	Analyze torsion in circular shafts and evaluate torsional stress, modulus of rigidity, and

			strain energy in shear and torsion.
IV	Bending of beams due to transverse load, shear force and bending moment diagrams, pure bending, bending stresses in beams, simple bending formula, flexural rigidity, section modulus, and shear stresses in bending of beam	09	Analyze bending of beams under transverse loads using shear force and bending moment diagrams, and apply bending stress formulas including flexural rigidity and section modulus.
V	Combined bending, torsion and axial thrust	04	Analyze and evaluate the effects of combined bending, torsion, and axial thrust on structural members.
VI	Bending of non-symmetric sections, shear flow, shear centre for thin walled section	05	Analyze bending of non-symmetric sections and determine shear flow and shear centre in thin-walled structures.
VII	Deflection of beams subjected to transverse forces, integration method, moment-area method, strain energy in bending, theorem of Castigliano and applications	08	Determine beam deflections under transverse loading using integration and moment-area methods, and apply strain energy principles and Castigliano's theorem.
VIII	Elastic theories of failure and applications	02	Apply elastic theories of failure to assess the safety and design of structural and mechanical components under complex loading.

Course Outcome	After completing this Course, the students should be able to 1. Explain the fundamental concepts of stress, strain, and their relationship in materials under different loading conditions. 2. Apply the principles of equilibrium of deformable bodies to analyze axial, torsional, and bending stresses in structural elements. 3. Analyze shear force and bending moment distributions in beams and determine bending and shear stresses. 4. Evaluate the deflection of beams using methods like double integration, moment-area and Castigliano theorems. 5. Assess the failure theories (Maximum Normal Stress, Maximum Shear Stress, Von Mises) for structures and design simple structural elements (e.g., beams, shafts, columns) under axial, bending, and torsional loads within safe limits using suitable factors of safety. 6. Interpret and correlate material behavior from experimental stress analysis techniques, such as strain rosette and draw Mohr's circle.

Learning Resources	**Text Book**: 1. Elements of Strength of Materials - S.P. Timoshenko and D.H. Young. **Reference Books**: 1. Mechanics of Materials – E. Popov 2. A Text Book of Strength of Materials – R.K. Bansal 3. Strength of Materials – F.P. Beer and E.R. Johnston Jr. 4. Strength of Materials (Vol. 1) – D.S. Prakash Rao

Course Code	AE2103N	Course Name	Numerical Methods and Computational Tools	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	Basic Mathematics	Co-requisite Courses	Nil	Progressive Courses	FEM Course & CFD course
Course Offering Department		Aerospace Engineering & Applied Mechanics		Data Book / Codes/Standards	Nil

Course Objectives	
	• To learn various numerical methods necessary to solve problems in aerospace engineering • To gather the introductory concept to study FEM

Module	Syllabus	Duration (class-hour)	Module Outcome
I	**Solution for linear systems of equation**: Elementary definitions related to matrix operation – matrix norm – consistency of the system – stability of the system – diagonal dominance & positive definiteness – direct methods of solution (inversion, Gauss method with normal & partial pivoting, Gauss-Jordan method, LU decomposition, Cholesky decomposition) – iterative methods and convergence study (Gauss-Siedel, Jacobi) – application to physical systems, Solution for nonlinear system of equations: Newton's vector method	08	Will learn various methods for solving systems of equation
II	**Eigen values and eigen vectors**: Characteristic polynomials – eigen pair – power method, inverse power method, shifted inverse power method – application to physical systems	04	Will learn various methods for eigen value probems
III	**Numerical differentiation**: Approximation of derivatives (forward, backward, central) – error analysis – numerical difference formulae	04	Will learn various numerical methods for differentiation
IV	**Numerical integration**: Closed Newton-Cotes quadrature – composite and recursive rule – error analysis – adaptive quadrature – Gaussian quadrature	06	Will learn various numerical methods for integration
V	**Solution to ODE**: Initial value problem using various approaches (Taylor, Picard, Euler, Heun, 4th Runge-Kutta, Predictor-Corrector) – error analysis – system of differential equations – higher order differentia l equations. Boundary value problems – application to physical systems	07	Will learn various numerical methods for solving ordinary differential equations

VI	**Solution to PDE**: Equation classification – solution using finite difference analogue – Jacobi & Gauss-Siedel approach for elliptic PDE – explicit (Bender-Schmidt) & implicit (Crank-Nicholson) approach for parabolic PDE – implicit & explicit approach for hyperbolic PDE – application to physical systems	06	Will learn various numerical methods for solving partial differential equations
VII	**Introduction to computational tool** : Definition – DOF, nodes, element – direct stiffness method – natural and geometric boundary condition – element characteristic matrix – derivation of element stiffness matrix for bar and beam element – element assembly – several approaches for imposing boundary conditions – briefing on bandwidth, node numbering, matrix sparsity etc. – hand computation of several problems of basic level.	07	Will learn the basics of FEM

Course Outcome	• Will be able to write codes for various analytical processes by using numerical methods • Will gather introductory concept for studying FEM in higher semester.

Learning Resources	1. Numerical methods using MATLAB, Mathews & Fink, PHI 2. Introductory methods of numerical analysis, Sastry, PHI 3. Concepts and applications of finite element analysis, Cook et al., John Wiley & Sons.

Course Code	AM2102N	Course Name	Rigid Body Dynamics	Course Category	ESC	L	T	P
						3	0	0

Pre-requisite Courses	Engineering Mechanics	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department		Aerospace Engineering and Applied Mechanics		Data Book / Codes/Standards	Nil

Course Objectives	
	1. Understanding basic laws and principles of plane kinematics and kinetics of rigid bodies. 2. To learn fundamental concepts and principles of rigid body kinetics 3. Application of Newton's second law to solve problems for rigid bodies in rotating and non-rotating frames. 4. To understand the fundamentals of free and forced vibrations. 5. To develop analytical competency in solving problems.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	**Introduction:** Kinematics and dynamics, frames of reference, coordinate systems, particle and rigid bodies, scalars, vectors, and tensors Illustrative problems	02	• Develops a conceptual foundation for motion analysis. • Equips students to distinguish between types of motion and physical quantities (scalar/vector/tensor). • Prepares for coordinate-based analysis of motion.
II	**Kinetics of systems of particles and variable mass problems** Illustrative problems	07	• Enables to apply Newton's laws to collection of particle systems in real-world.
III	**Kinetics of particles in an accelerating frame of reference:** • Frames with Linear Acceleration, D'Alembert's Principle • Motion in Rotating Frame of Reference Illustrative problems	07	• Allows motion analysis in non-inertial frames, critical for vehicle dynamics and rotating systems. • Provides foundational understanding of fictitious forces and frame transformations.
IV	**Dynamics of rigid bodies in plane motion**: • Definition of Rigid Bodies and Kinematic Constraints	13	• Equips to analyze rigid body dynamics in 2D**.**

	• Kinematics of Rigid Bodies – Translational Motion, Pure Rotation, and General Motion • Linear and Angular Momentum, Kinetic Energy • FBD and Laws of Motion • Conservation Principles – linear and angular Momentum, Energy • Impulsive Forces and Moments Illustrative problems		• Enables the use of energy and momentum principles for force/motion predictions to rigid bodies.
V	**Dynamics of Motion in Three Dimensions**: • Chasle's Theorem and Spherical Motion • Angular Momentum and Inertia Tensor, Kinetic Energy • Free Motion of an Axisymmetric Body – Body cone and Space cone • Euler's Equation, Modified Euler's Equation, Euler Angles, Gyroscopic Action. Illustrative problems	13	• Develops the ability to analyze 3D rotational motion and gyroscopic dynamics. • Introduces tools for advanced structural systems. • Strengthens understanding of complex rigid body behaviour in space.

Course Outcome	Upon completing this course, students will be able to: • Determine the kinematic relationships between position, velocity, and acceleration for two-dimensional motion of systems of particles and rigid bodies • Apply Newton's equation in two dimensions to calculate the motion due to applied forces or to calculate the forces resulting from a specified motion. • Analyze the two-dimensional motion of particles and rigid bodies using conservation laws for energy, momentum, and angular momentum. • Apply dynamics concepts to the design of simple machines and structures to accomplish a specific task

Learning Resources	• Engineering Mechanics: Dynamics – Meriam & Kraige

Course Code	AE2104N	Course Name	Flight Mechanics	Course Category	PC	L	T	P
						3	1	0

Pre-requisite Courses	Elementary mechanics	Co-requisite Courses	Aerodynamics, propulsion, Aircraft structures	Progressive Courses	Advanced aircraft design, Unmanned Aerial Vehicles
Course Offering Department		Aerospace Engineering and Applied Mechanics		Data Book / Codes/Standards	See learning Resources

Course Objective	To provide a solid foundation in aircraft static stability, control, and performance. Students will analyze the influence of components and control surfaces on stability, evaluate performance in steady and accelerated flight, and understand key aspects of take-off, landing, and maneuvering.

Module	Syllabus	Classes	Outcome
1	**Static Stability and Control:** Basic Concepts of Airplane Stability and Control; Static Stability and Dynamic Stability; Controllability.	2	Understand basic concepts of aircraft stability, controllability, and static vs. dynamic stability.
2	**Longitudinal Stick–Fixed Static Stability and Control:** Criterion of Longitudinal Static Stability, Contribution of Aircraft Components, Wing Contribution, Horizontal Tail Contribution, Fuselage Contribution, Power Plan Contribution, Stick-Fixed Neutral Point, Static Margin.	8	Analyze aircraft components' contributions to longitudinal static stability and determine static margin.
3	**Longitudinal Control:** Elevator, Elevator Power, Elevator Effectiveness, Elevator Angle to Trim.	5	Evaluate elevator effectiveness, trimming, and control force requirements in pitch control.
4	**Longitudinal Stick-Free Static Stability:** Hinge Moments and Effect of Freeing the Stick, Trim Tab, Stick Forces and Stick Force Gradients, Analysis of Stick-Free Static Stability, Floating Angle of Elevator, Static Stability in Stick-Free Condition, Stick-Free Neutral Point, Effect of Acceleration, Stick-Fixed Maneuver Point; Stick Force Gradient in Pull-Up; Stick-Free Manoeuvre Point.	8	Understand stick-free effects, hinge moments, and maneuver points affecting stability.
5	**Directional Static Stability and Control:** Criteria of Directional Static Stability, Side Slip and Yaw, Contribution of Wing, Fuselage, Power and Vertical	5	Assess directional stability factors and control in

	Tail to Directional Stability, Pedal Fixed and Pedal-Free Directional Stability, Directional Control, Adverse Yaw and Cross Wind Take-off and Landing, Control in asymmetric power, steady flight after engine failure and minimum control speed, Need for rudder deflection in a coordinated turn ,Effect of large angle of side slip, rudder lock and dorsal fin, Prevention of rudder lock		asymmetric conditions and yaw-related issues.
6	**Lateral Static Stability and Control:** Criteria of Lateral Static Stability, Rolling Moment, Dihedral Effect and Contributions of Wing, Fuselage, Vertical Tail, Propeller and Flaps, Roll Control, Aileron, Rolling Moment due to Aileron, Damping Moment, Rate of Roll, Aileron Power, Aerodynamic Balancing, Tabs, Elevons.	4	Examine lateral stability criteria and control using ailerons and other aerodynamic surfaces.
7	**Airplane Performance in Steady Flight:** Governing Equations of motion, Thrust Required, Fundamental Parameters, Thrust Available and Maximum Velocity, Power Required, Power Available and Maximum Velocity, Rate and Time to Climb, Range and Endurance	10	Calculate steady flight performance parameters like thrust, power, climb rate, range, and endurance.
8	**Airplane Performance in Accelerated Flight:** Level Turn, Pull-up and Pull-down Maneuvers, Energy Concepts, Accelerated Rate of Climb, Take-off Performance, Landing Performance	10	Analyze aircraft behavior and limits in maneuvers, take-off, and landing performance.

Course Outcome	By the end of this course, students will be able to: 1. Explain static and dynamic stability concepts and types. 2. Analyze longitudinal stick-fixed and stick-free stability, including component contributions and control surface effects. 3. Evaluate elevator, rudder, and aileron effectiveness in various flight conditions. 4. Assess lateral and directional stability, including asymmetric and crosswind effects. 5. Compute key performance parameters in steady and accelerated flight. 6. Estimate climb, range, endurance, and maneuvering performance using analytical and energy methods.

Learning Resources	• Flight Stability and Automatic Control by Robert Nelson, McGraw Hill 2nd Edition • Airplane Performance, Stability and Control (1949, Wiley) - Courtland D. Perkins, Robert E. Hage – • Introduction to flight by Anderson, Jr. J.D., McGraw Hill 2005. • Aircraft Performance and Design, J. D. Anderson, Jr., McGraw-Hill

Course Code	AM2171N	Course Name	Strength of Materials Laboratory	Course Category	ESC	L	T	P
						0	0	3

Pre-requisite Courses	Nil	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department		Aerospace Engineering and Applied Mechanics		Data Book / Codes/Standards	Nil

Course Objectives	
	1. Introduce experimental procedures and common measurement instruments, equipment, and devices. 2. To determine experimental data, include the hardness test, universal testing machines and torsion equipment. 3. To determine experimental data for the impact test and buckling analysis. 4. To determine deflection of beam subjected to bending load. 5. Provide physical observations to complement concepts learnt.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	Introduction to Equipment and Facilities	03	• **Identify and describe** the purpose and function of standard laboratory equipment and facilities relevant to their field of study. • **Understand the operating principles** and safe handling procedures of laboratory instruments.
II	Rockwell Hardness Test	03	• Understand the significance of different Rockwell scales (e.g., B, C). • Recognize suitable applications for Rockwell hardness testing in quality control and material selection.
III	Brinell Hardness Test	03	• Measure and calculate the diameter of the indentation to determine the hardness number. • Interpret hardness values in relation to material properties like strength and wear resistance.
IV	Tension Test of Metals	03	• Calculate mechanical properties including Young's modulus, yield strength, tensile strength, ductility (%

			elongation and reduction in area).
V	Experiment on Strain Hardening of Metals	03	• Understand the relationship between plastic deformation and increased material strength.
VI	Torsion Test of Circular Shaft	03	• Calculate shear stress, shear strain, modulus of rigidity (rigidity modulus), and torsional stiffness.
VII	Experiment on Impact Test	03	• Relate impact test results to material properties such as brittleness, ductility, and fracture toughness.
VIII	Buckling or Critical Load for Long Column	03	• Calculate critical loads for columns with various boundary conditions (e.g., pinned-pinned, fixed-pinned).
IX	Fatigue Testing of Metals (Lecture & Demonstration)	03	• Understand the importance of fatigue testing in material selection and design of durable components.
X	Measurement of Beam Deflection Using Dial Gauge	03	• Understand the working principle of a dial gauge and its suitability for precise deflection measurement.
	End Test	03	• Evaluating the Performance
	Viva-Voce	03	• Evaluating the Performance

Course Outcome	At the end of the course, the student will be able to: • Know about the operational details of various testing machines for materials. • Analysis of structural members subjected to tension, torsion, bending, strain hardening and fatigue using the fundamental concepts of stress, strain, and elastic behaviour of materials. • Write a technical laboratory report and to interpret technical graphs.

Learning Resources	• Strength of Materials Laboratory Manual

Course Code	AE2171N	**Course Name**	Fluid Dynamics Laboratory	**Course Category**	ESC	L	T	P
						0	0	3

Pre-requisite Courses	Nil	**Co-requisite Courses**	Fluid Dynamics	**Progressive Courses**	Nil
Course Offering Department		Aerospace Engineering & Applied Mechanics		**Data Book / Codes/Standards**	Nil

Course Objectives	• Students gain practical experience of flow behaviour through experiments • They learn to measure pressure, flow rate, and other parameters such as boundary layer thickness, orifice coefficients, friction factor (pipe flow), minor loss coefficients, impact force of a jet, etc. • They learn to perform calibration of flow device

Module	**Syllabus**	**Duration (class-hour)**	**Module Outcome**
I	Introduction and orientation of Fluid Dynamics laboratory	3	• Learn the rules, guidelines and safety protocol (DOS and DON'TS) of performing laboratory experiments. • Be introduced to the experimental set-ups, in general.
II	Verification of Bernoulli's Theorem	3	• Measure total (Bernoulli) head along a slightly converging rectangular duct, • Plot the actual EGL and HGL obtained during the experiment
III	Osborne Reynolds' Demonstration	3	• Visualize laminar, transitional and turbulent flow in a tube using a streakline, • Verify the values of critical Re for a circular tube
IV	Measurement of Force of Impact of a Jet	3	• Investigate the reaction forces produced by a fluid jet on stationery vanes with deflector angle = 30^{o}, 90^{o}, 120^{o} and 180^{o}, • Compare the impact force predicted by theory with the experimental data
V	Determination of Orifice Coefficients	3	• Determine the Coefficient of Velocity, Coefficient of Discharge and Coefficient of Contraction for a small orifice located at the vertical wall of a big water tank,

			• Understand the role of orifice coefficients on flow rate measurements
VI	Frictional loss in Commercial Pipes	3	• Investigate the friction factor variation with the Reynolds number for fully developed flow through commercial pipes,
VII	Estimation of Minor Loss Coefficients of various Pipe fittings	3	• Measure the minor loss coefficients for sudden expansion, sudden contraction, mitre bend, long and short bends, etc. • Assess the dependence of minor loss coefficients on flow rate
VIII	Calibration of an Orifice-meter	3	• Learn the calibration procedure of an Orifice-meter and plot the calibration curve
IX	Determination of Pressure Characteristics of a Venturi-tube	3	• Determine the pressure characteristics in a Venturi-tube, • Estimate the pressure-recovery coefficient of the diffuser
X	Measurement of Boundary layer thickness on a flat plate	3	• Measure boundary layer thickness at three different locations on a flat plate • Perform boundary layer calculations (*e.g.*, displacement thickness and momentum thickness) and estimate boundary layer growth rate
XI	Arrear class	3	NA
XII	Viva-voce examination	3	NA

Course Outcome	On successful completion of this course, • Students learn to apply fundamental principles like Bernoulli's equation and the conservation of mass and energy to solve real-world fluid flow problems and understand the behaviour of fluids in various engineering applications • Students will develop practical skills in conducting experiments, collecting data, analyzing results, and reporting findings

Learning Resources	4. Laboratory instruction manuals of FM Lab

Course Code	AE2172N	**Course Name**	Machine Drawing	**Course Category**	PC	L	T	P
						0	0	3

Pre-requisite Courses	Engineering Graphics	**Co-requisite Courses**	None	**Progressive Courses**	CAD Drawing
Course Offering Department		Aerospace Engineering and Applied Mechanics		**Data Book / Codes/Standards**	None

Course Objective	To equip students with the skills to interpret and create accurate mechanical drawings, including parts and assemblies, using standard drafting practices and conventions.

Module	**Syllabus**	**Duration (class-hour)**	**Module Outcome**
I	Development of Surfaces	06	• Students will learn to draw the lateral surface of different hollow solids, truncated in various ways.
II	Rivet Joints, Nuts & Bolts	09	• Students will learn to draw two views of Rivet joints (Lap & Butt), and three views of Nuts and Bolts (Hexagonal & Square), along with its assembly.
III	Interpenetration of Solids	06	• Students will learn to draw one or two views of the curves, generated due to intersection of two different solids, in different combinations and different orientations.
IV	Section of Machine Parts	03	• Students will learn to draw three views of various machine parts, having sections in different planes.
V	Component drawing and Assembly drawing of Machines	15	• Students will learn to draw three views of all the components of various machines and also to draw the assembled views having sections.
End Test		03	

Course Outcome	• Understand and apply the principles of machine drawing and represent mechanical components using standard drawing conventions. • Interpret orthographic views, sectional views, and dimensioning systems used in machine drawings. • Visualize and communicate design ideas effectively through technical drawings.

	• Analyze and understand the functional relationships between assembled components in a machine.

Learning Resources	**Text Book:** 1. Engineering Drawing – N.D. Bhatt 2. Machine Drawing – N.D. Bhatt **Reference Books:** 1. Engineering Graphics – Venugopal

Course Code	AE2173N	Course Name	Numerical Method and Computational Tools Laboratory	Course Category	PC	L	T	P
						0	0	3

Pre-requisite Courses	Basic programming, Numerical Methods	Co-requisite Courses	Nil	Progressive Courses	Computational Fluid Dynamics
Course Offering Department		Aerospace Engineering & Applied Mechanics		Data Book / Codes/Standards	Nil

Course Objective	The objective of this course is to equip students with practical skills in implementing numerical methods through programming. Students will learn to apply numerical integration techniques such as the Midpoint, Trapezoidal, and Simpson's rules, and solve ordinary and partial differential equations using Euler's and Runge-Kutta methods. Emphasis is placed on understanding numerical errors, algorithm development, and solving real-world mathematical problems through code implementation in a computing environment.

Module	Name of Experiments	Duration (class-hrs)	Module Outcomes
1	Introduction to Numerical Computing and Basic programming	3	Basics of numerical error, floating point representation, introduction to programming environment.
2	To Find out the root of the Algebraic and Transcendental equations using Bisection method	3	Understanding the concept of root finding of equations, the iterative process using the bisection method.
3	To Find out the root of the Algebraic and Transcendental equations using Newton-Raphson method.	3	Module outcomes include the ability to derive and apply the Newton-Raphson formula to solve practical problems, analyze its convergence properties, and understand its limitations.
4	Solution of Linear Systems- Jacobi/ Gauss-Seidel Method	6	To find approximate solutions of linear systems of equation, understanding the iterative nature of these methods, their convergence criteria.

5	Numerical integration by Midpoint Rule, Trapezoidal Rule, Simpson's Rule	6	Implement the Midpoint Rule for numerical integration of definite integrals. Code the Trapezoidal Rule to approximate integrals and compare with analytical results. Implement Simpson's 1/3 Rule and 3/8 Rule for high-accuracy integration.
6	Composite Integration Methodsand Error Analysis of Integration Methods	3	Apply Midpoint, Trapezoidal, and Simpson's rule over subintervals. Analyze the errors and convergence behavior of implemented methods.
7	Solving ODEs using Euler's method	3	Develop programs to solve simple first-order ODEs using Euler's method.
8	Runge-Kutta Methods	3	Implement 2nd and 4th order Runge-Kutta methods to solve initial value problems.
9	Solving Heat Equation (1D)	3	Develop program for explicit method to solve 1D unsteady heat conduction equation.
	End-test	3	
	Viva Voce	3	

Course Outcome	• Find out the root of the Algebraic and Transcendental equations using different methods • Develop and implement algorithms to find approximate solutions of linear systems of equation • Apply numerical integration techniques (Midpoint, Trapezoidal, Simpson's rules) and analyze associated errors. • Develop and implement algorithms for solving ordinary differential equations using Euler and Runge-Kutta methods. • Solve basic partial differential equations numerically, such as the 1D unsteady heat equation using finite difference methods.

4th Semester Courses Syllabi

B. Tech in Aerospace Engineering

Course Code	AE2201N	Course Name	Aerodynamics I	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	Fluid Mechanics, Differential and Integral calculus	Co-requisite Courses	Nil	Progressive Courses	High Speed Aerodynamics
Course Offering Department		Aerospace Engineering and Applied Mechanics		Data Book / Codes/Standards	Nil

Course Objectives	To equip students with the skills to effectively analyse the lift and drag of forces on aerofoils and wings in the low-speed regime. Introduce students with classical potential flow theory of aerofoil and wings; and implement these techniques computationally. Equip students with the understanding of different types of wind tunnels and state of the art instrumentation for measurement of aerodynamic characteristics in wind tunnel experiments.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	**Equations in Ideal flow:** Rotational and Irrotational flow; velocity potential, Circulation and vorticity, vortex tube, Kelvin's circulation theorem, Stokes' Integral Theorem; Generalised Bernoulli's equation.	4	Students will have the understanding of the fundamentals of ideal fluid flow together with basic concepts of vorticity transport
II	**Applications:** Examples of 2D potential flow, Laplace equation and principle of superposition, flow around a non-lifting cylinder, lifting cylinder, Complex Potential Function and Conformal mapping, Solution of 2D potential flow problems using complex analysis, Flow with Circulation; Kutta–Joukowski theorem; The Joukowski transformation and Joukowski airfoils; Vortex Motion.	11	Students will have the understanding of potential flow theory and fundamental theorems of the lifting theory

III	**Incompressible flow over airfoils and finite wings:** Classical Aerofoil Theory – Camber and Thickness Problems; Downwash and induced drag, Biot-savart law and Helmholtz's theorems; Prandtl's lifting line theory; Lifting surface theory.	11	Students will be able to analyze Aerofoil and Three dimensional wings and evaluate different aerodynamic characteristics
IV	**Computational methods:** Source and Vortex Panel Methods.Vortex lattice method; 3D source and Doublet; Algorithm and development of panel method code.	10	Students will be able to computationally implement potential flow theory in evaluation of the aerodynamic characteristics
V	**Wind Tunnel Testing:** Classification and types; special problems of testing; Layouts; sizing and design parameters, Model mount, Model fabrication, Forces/moments measurements and balance calibration, Pressure measurements - Pressure scanners and data acquisition, Multi-holes probes, Velocity measurements – Pitot tube, Hot wire anemometry, laser techniques, Particle Image Velocimetry (PIV); visualization techniques - smoke, Tufts, Pressure sensitive paint, laser sheet, and surface oil flow.	6	Students will have thorough understanding on the wind tunnel construction, model testing and associated instrumentation and data outputs in estimation of the aerodynamic parameters.

Course Outcome	• Understanding and implementation of the analysis of inviscid incompressible flows and the application of these to the flow over airfoils and finite wings. • Computationally implement Source and Vortex Panel Methods, Vortex lattice method, 3D source and Doublet. • Thorough understanding of wind tunnels and wind tunnel tests and associated measurement techniques for the measurement of aerodynamic moments, lift, drag, pressure and the velocity distribution and thereby develop the ability to apply these in wind tunnel testing.

Learning Resources	1. J D Anderson, Jr., *Fundamentals ofAerodynamics,* McGraw-Hill International 2. E L Houghton and A E Brock, *Aerodynamics for Engineering Students*, Edward Arnold 3. E L Houghton and N B Carpenter, *Aerodynamics for Engineering Students*, Edward Arnold 4. J Katz and A E Plotkin, *Low Speed Aerodynamics,* Cambridge University Press 5. Rae, W.H. and Pope, A., "Low Speed Wind Tunnel Testing", John Wiley Publication, 1984.

Course Code	AE2202N	Course Name	Aerospace Structure – I	Course Category	PC	L	T	P
						3	1	0

Pre-requisite Courses	Basic Mathematics & Strength of Materials	Co-requisite Courses	Nil	Progressive Courses	Aerospace Structure – II
Course Offering Department		Aerospace Engineering & Applied Mechanics		Data Book / Codes/Standards	Nil

Course Objectives	To cover up the items of strength of materials which could not be taught in previous course, due to time constraint and also to give an overview to some important topics related to aerospace structure.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	**Basic Elasticity** : Introduction to tensor – generalized coordinate transformation – stress tensor at a point – principal stress & stress invariant – analysis of strain – constitutive & compatibility equation in 3D Cartesian coordinate – introduction to plane stress – introduction to plane strain.	12	Basic conception of 3D structure will be built up
II	**Virtual Work**: Principle of VW for particle & rigid body – VW done by axial forces, shear forces, bending moment and torsion – application to beams and trusses.	12	A new solution technique for structures will be learnt
III	**Energy Methods** : Strain energy due to axial force, bending and torsion with applications – Complimentary energy – total potential energy; total complimentary energy and principles of stationary value – application to determinate & indeterminate problems (beams, frames, rings)	12	Another new solution technique of structures will be learnt
IV	**Structural Instability** : Short and long columns, critical load, column with eccentric loading – 15 transversely loaded column (beam-column) – energy method for buckling loads in column – effect of initial imperfection in column & Southwell plot	12	Concept a special type of structural member will be built up

V	**Introduction to Plates** : Basic parameters, governing differential equation, boundary conditions, Navier's Method of solution	08	Will be helpful to study various aerospace structures

Course Outcome	This course will serve as a pre-requisite to Aerospace Structure course

Learning Resources	1. Elasticity, Martin H. Sadd 2. Theory of Elasticity, Timoshenko & Goodier 3. Aircraft Structures, T.H.G. Megson 4. Applied Elasticity, Zhi Lun Xu 5. Foundations of Solid Mechanics, Y.C. Fung

Course Code	AE2203N	Course Name	Theory of Vibration	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	Engg. Mech, Strength of Materials, Mathematics	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department		Aerospace Engineering & Applied Mechanics		Data Book / Codes/Standards	Nil

Course Objectives	This preliminary course instils the knowledge of vibration of single degree of freedom system as well as multi-degree of freedom system with and without different types of damping, continuous systems, detrimental effects of vibration, reduction or complete isolation of vibrations to avoid unwanted failure of structures, different types of analysis methods and different types of instruments used to measure vibration.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	Introduction; Oscillatory motion – Harmonic motion, Periodic motion, Vibration Terminology	3	Familiar with different oscillatory motions and vibration terminology.
II	Free Vibration of Single Degree of Freedom System: Vibration model and equations of motion, Natural frequency, Energy method, Rayleigh method, Different Kinds of Damping	6	Acquainted with different types of damping and methods to determine fundamental frequency of SDOF system.
III	Forced vibration of Single Degree of Freedom System: Forced harmonic vibration, Rotating unbalance, Rotor unbalance, whirling of rotating shafts, Support motion, Vibration isolation, Energy dissipation, Vibration measuring instruments	8	Become familiar with effects of harmonic disturbance due to rotating unbalance and support motion and instruments used and able to predict the method of vibration isolation.
IV	Multi-degree of freedom systems: Normal mode vibration, Coordinate coupling, Forced harmonic excitation	7	Familiar with MDOF system and able to determine the natural frequencies of MDOF system.
V	Properties of vibrating systems: Flexibility matrix, Stiffness matrix, Stiffness of beam elements, Eigenvalues and eigenvectors, Orthogonal properties of eigenvectors, Modal matrix, Modal damping in forced vibration	10	Able to evaluate natural frequencies of MDOF systems using modal matrix.

VI	Normal mode vibration of continuous systems: Vibrations of rods, Euler equation of beams	5	Able to derive the frequency equation and eigenvalues of different continuous systems.
VII	Approximate numerical methods: Rayleigh method, Dunkerley's method	3	To determine the fundamental frequencies of lumped mass system and continuous system.

Course Outcome	Students are able to do vibration analysis of different structures and predict the methods to avoid failure of the structure due to vibration and have fundamental theoretical and practical knowledge to pursue higher study.

Learning Resources	1. W T Thompson, Theory of Vibration with Applications, George Allen 2. L Meirovitch, Analytical Methods in Vibration, MacMillan 3. V P Singh, Mechanical Vibration, Dhanpat Rai & Co. 4. A C Fung, *Introduction to Aeroelasticity* 5. R L Bisplinghoff, H Ashley, *Principle of Aeroelasticity,* Wiley

Course Code	AE2204N	Course Name	Theory of Aircraft Propulsion	Course Category	PC	L	T	P
						3	1	0

Pre-requisite Courses	Thermodynamics	Co-requisite Courses	Aircraft performance	Progressive Courses	Rocket propulsion
Course Offering Department		Aerospace Engineering & Applied Mechanics		Data Book / Codes/Standards	Nil

Course Objective	The objective of aircraft propulsion is to provide students with a thorough understanding of the fundamental principles and practical applications of aircraft propulsion systems. After completion of course, students will be able to: • Learn about different types of engines, their components, and performance characteristics. • To assess the performance of propulsion systems under various operating conditions, to understand the factors affecting engine efficiency and thrust. • Thermodynamic analysis of different components of aircraft engines • Importance of gas dynamics on aircraft thrust.

Module	Syllabus	Duration (class-hrs)	Module outcomes
Unit 1	**Introduction:** Real Brayton cycle, Brayton cycle modifications using intercooling, reheating, and regeneration, thrust equations, factors effecting thrust, aircraft performance and efficiencies, rate of climb, Breguet's equation, Numerical	**10**	Students will be able to understand basic principles of propulsion systems, analyze thermodynamic cycles, and evaluate engine performance parameters. Module will also help to understand engine components and functions.
Unit 2	**Gas Dynamics:** Variation of Gas Properties, static and stagnation properties, Speed of sound, Mach number, choking, Sonic conditions, Area velocity relationship, compressible fluid through nozzle, variables of flow in terms of Mach number, Shock waves, Numerical	**12**	Students will able to understand the fundamental principles of compressible flow, can analyze isentropic flows, and apply conservation laws to compressible flows
Unit 3	**Aircraft engines performance analysis:** Component Performance using thermodynamics, Turbojet, Turbojet with Afterburner, Turbofan – Separate Exhaust System, Turbofan with Afterburning - Separate Exhaust System, Turbofan with Afterburning - Mixed Exhaust Stream, Turboprop Engine;	**14**	Students will be able to understand the principles of various aircraft engine performances, evaluate performance of various engines, and can apply thermodynamic and fluid dynamic concepts.

	Turboshaft engine, Ramjet engine, Scramjet engine, Numerical		Both rotating and non-rotating aircraft engines will be covered in this module.
Unit 4	**Turbomachinery:** Dimensionless analysis, Model and prototype, Euler's equation, power generation and power absorbing turbomachines, Velocity triangles, Utilization factor, Degree of reactions, Analysis of axial and radial Compressor and Turbine, polytropic, stage, and overall Efficiencies, Numerical	**12**	Students will be able to understand fundamental concepts of turbomachinery, can apply fluid mechanics and thermodynamics to turbomachinery, and can analyze turbine and compressor performance. Module also helps student to interpret velocity diagrams, understand and analyze blade design principles.
Unit 5	**Inlets, Burner, and nozzle:** Inlets and intakes, subsonic, and supersonic inlets, Inlet Pressure Recovery, Types of burners used in aircraft engines, Burner Efficiency and Pressure Loss, performance analysis of burners, nozzle flow, types of nozzles, Exit Nozzle Loss	**8**	Students will be able to understand the role of engine subsystems, analyze supersonic and subsonic inlets, and can apply compressible flow principles to inlets and nozzles. Module will help to evaluate combustion process in burners.

Course Outcome	CO 1: Understanding Engine Types and Cycles CO 2: Engine Performance Analysis CO 3: Understanding Engine Components CO 4: Applying Theoretical Principles CO 5: Practical Application and Design

Learning Resources	1. J. D. Mattingly, Elements of Gas Turbine Propulsion, Tata McGraw Hill 2. Saeed Farokhi, Aircraft Propulsion, Wiley 3. Ahmed F. El-Sayed, Aircraft Propulsion and Gas turbine engines, CRC press

Course Code	AM2261N	Course Name	Viscous Flow	Course Category	OE1	L	T	P
						3	0	0

Pre-requisite Courses	Fluid Mechanics / Fluid dynamics	Co-requisite Courses	Nil	Progressive Courses	Propulsion, Micro and nano-scale Transport processes, Heat Transfer
Course Offering Department		Aerospace Engineering & Applied Mechanics		**Data Book / Codes/Standards**	Nil

Course Objectives	
	• To provide students with a fundamental understanding of viscous flow from an advanced point of view, with an emphasis on the analytical / mathematical treatment of laminar flows in both internal and external flow configurations. • Introduce topics of Aerodynamics (boundary layer theory, drag and lift, etc.) and Microfluidics (Low-Re hydrodynamics, lubrication theory) which is an emerging area of multidisciplinary research

Module	Syllabus	Duration (class-hour)	Module Outcome
I	**Exact solutions of governing equations**: Continuity and Equation of motion, Boundary conditions for viscous flow, Examples of exact solutions for concentric cylinders and parallel plates.	6	• Develop analytical ability for solving various laminar flow problems, • Understand the flow physics
II	**Dimensional analysis and Similitude**: Buckingham's Pi theorem; Scaling variables, nondimensionalisation of Navier-Stokes equations, dimensionless parameters and their physical interpretation; Geometric, kinematic and dynamic similarity, model testing in laboratory	6	• Learn the methods of performing scaling and dimensional analysis, • Understand scaling laws and apply them in wind tunnel testing and other applications
III	**Lubrication theory**: Hydrodynamic lubrication theory (*e.g.*, journal bearing)	4	• Formulate Reynolds lubrication equation, • Calculate pressure distribution and load bearing capacity
IV	**Low-Re hydrodynamics**: Stokes flow past a sphere, Electroosmotic flow,	6	• Analyse low-Re flows, • Realize their applications and physical implications

	Surface tension driven flow in micro-capillary		
V	**Boundary layer theory:** Boundary layer approximation, Laminar boundary layer equations, scaling estimates of characteristic boundary layer thickness, wall shear and friction coefficients ; Von Karman momentum integral equation and its applications; Similarity solution for laminar boundary layer, Effect of pressure gradient, Drag calculation based on control volume approach	8	• Formulate boundary layer equations and estimate the scale for BL thickness, • Evaluate skin friction drag for a flat surface, • Learn approximate methods for boundary layer calculation, • Understand the limitations of BL theory and Integral method
VI	**Turbulent boundary layer**: Turbulent boundary layer equations, structure of turbulent boundary layer, Integral estimates for turbulent boundary layer flow over a flat plate	3	• Understand the basics of various sublayers of a turbulent boundary layer, • Deduce composite formula for the drag coefficient for partly laminar partly turbulent BL
VII	**Boundary layer separation**: Effect of pressure gradient on boundary layer, and prediction of separation point, Methods of preventing boundary layer separation	3	• Understand the physics behind boundary layer separation, • Learn design criteria for drag reduction
VIII	**Flow over Immersed Bodies**: Drag and Lift, streamlined body and bluff body, friction and pressure drag; Flow past a smooth cylinder, force coefficients and characteristic area, Lift generation on a rotating cylinder, lift on airfoil, aerodynamics of sports ball	6	• Understand the roles of flow separation and Reynolds number on drag and lift coefficients, • Calculate drag and lift for some regular and irregular shaped bodies

Course Outcome	On successful completion of this course, students should be able to: • Develop an understanding of the concepts of boundary layer, drag and lift, lubrication theory, micro-flows, etc. • Improve their overall analytical ability as both exact and approximate methods of the solution are discussed • Learn dimensional analysis and scaling laws and their applications in wind tunnel testing and many more applications • Learn design aspects of various devices and instruments (*e.g.*, journal bearing, drag reduction, lift generation)

Learning Resources	5. Viscous Fluid Flow, F.M. White, McGraw-Hill International 6. Boundary Layer Theory, H. Schlichting, McGraw-Hill 7. An Introduction to Fluid Dynamics, G.K. Batchelor, Cambridge University Press 8. National Committee for Fluid Mechanics Films (NCFMF) https://web.mit.edu/hml/ncfmf.html

Course Code	AE2271N	Course Name	Computational Solid Mechanics Laboratory	Course Category	PC	L	T	P
						0	0	3

Pre-requisite Courses	Preliminary knowledge of strength of materials	Co-requisite Courses	None	Progressive Courses	B.Tech Project
Course Offering Department		Department of Aerospace Engineering and Applied Mechanics		Data Book / Codes/Standards	None

Course Objective	To equip students with hands-on proficiency in using finite element analysis software to model, analyze and interpret results for solid mechanics problems.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	Introduction, discretization, approximation and exact solutions, development of stiffness matrix of spring and bar elements and their assembling's	06	Students will learn about the initial basics of the finite element method.
II	Introduction to ANSYS Workbench, pre-processing, meshing, structural analysis, post-processing	03	Students will learn about the basics of Ansys Workbench.
III	Exercises using ANSYS Workbench: stress concentration problems, contact of aircraft engine blade and disc, deflections of an aircraft wing box	09	Students will learn more details about Ansys Workbench. They will be to model and solve structural problems.
IV	Introduction to ANSYS APDL, pre-processing, solution, general post-processing	06	Students will learn about the ~~very~~ basics of Ansys APDL.
V	2D and 3D Problems using ANSYS APDL	15	Students will learn more details about Ansys APDL. They will be to model and solve structural problems.
Viva voce		03	

Course Outcome	• Use finite element analysis software to model and analyse solid mechanics problems having structural and mechanical components. • Interpret the results of simulations to assess stress, strain, and deformation. • Validate simulation results by comparing them with theoretical predictions and experimental data.

Learning Resources	1. A First Course in the Finite Element Method, Daryl L. Logan 2. ANSYS documentation

Course Code	AE2272N	Course Name	CAD Laboratory	Course Category	PC	L	T	P
						0	0	3

Pre-requisite Courses	Preliminary knowledge of strength of materials	Co-requisite Courses	None	Progressive Courses	B.Tech Project
Course Offering Department		Department of Aerospace Engineering and Applied Mechanics		Data Book / Codes/Standards	None

Course Objective	To provide students with practical skills in computer-aided design through hands-on experience in 2D and 3D modeling, parametric design in accordance with industry standards using CAD software.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	**Introduction to CAD Modeling** Overview of CAD software and applications in engineering, basics of 2D sketching and coordinate systems, introduction to geometric modeling techniques	06	Students will understand the fundamentals of CAD systems and geometric modeling concepts.
II	**2D Drafting and Dimensioning** Creating and editing 2D drawings, applying dimensions, annotations, and tolerances	06	Students will be able to create precise 2D engineering drawings with standardized dimensioning and annotations.
III	**3D Solid Modeling and Assemblies** Creating 3D features: extrusion, revolve, sweep, loft, editing and modifying 3D models, creating assembly models	12	Students will be able to construct detailed 3D solid models and assemble components using CAD software.
IV	**Parametric Modeling and Design Exercises** Introduction to parametric design and constraints, creating parametric parts and assembly, hands-on exercises involving real-world components and design challenges	15	Students will apply parametric design techniques to develop and modify CAD models efficiently.
Viva voce		03	

Course Outcome	• Students will develop proficiency in creating 2D and 3D models using CAD software. • Students will apply design constraints and standards to produce accurate and functional engineering drawings. • Students will demonstrate the ability to perform parametric modeling and assemble parts for complete design representation.

Course Code	AE2273N	Course Name	Vibration Laboratory	Course Category	PC	L	T	P
						0	0	3

Pre-requisite Courses	Nil	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department		Department of Aerospace Engineering and Applied Mechanics		Data Book / Codes/Standards	Nil

Course Objectives	To enhance the corresponding Theory course knowledge by experimental endeavour. To give students hands on experience on basic vibration characteristics as well as the methods used to analyze vibration characteristics of complex systems

Module	Syllabus	Duration (class-hour)	Module Outcome
I	Introduction to Different Components of Fundamental Vibration Trainer	03	Familiarization with different components of VFT and there uses.
II	Detailed demonstration of Software related to Different Experiments	03	To understand how software analyze data to calculate different characteristics.
III	Familiarisation to Data Acquisition Device	03	To understand how the system captures and analyze different type of experimental data.
IV	Demonstration of different components of Work Bench	03	To familiarize students how different components work together to produce fruitful results
V	Experiment on Vibration of Single DOF Systems – i) Basic Characteristics, ii) Harmonic Excitation	03	Knowledge of Natural frequency Concept of Transient and steady state forced vibration
VI	Determination of Damping ratio for SDOF system with damped vibration	03	Knowledge of variation of damping for different damping medium
VII	Base Excitation Experiment	03	Knowledge of force and displacement transitivity
VIII	Reporting on experiments of SDOF systems	03	Intermediate scrutiny of laboratory report writing and corresponding corrections

Learning Resources	Department-prepared CAD laboratory manual with step-by-step exercises

IX	Experiment on Vibration of Two DOF Systems	03	Understanding effect of coupled and uncoupled vibration
X	Experiment on Torsional Vibration	03	Understanding effect of torsional stiffness on torsional vibration
XI	Beam Lateral Vibration - Concept of ODS	03	Knowledge of analyzing vibration of continuous systems.
XII	Demonstration of Tuned Mass Damper System	03	Concept of vibration controlling device.
	Viva voce	03	Evaluation of overall knowledge development on the entire course.

Course Outcome	This experimental course will help to develop practical knowledge regarding different vibration characteristics of both discrete systems as well as distributed structural systems. The course also give an idea to students regarding control of severity of structural vibration

Learning Resources	Instrument Manual and Laboratory Instruction sheets developed exclusively for the laboratory course.

Course Code	AE2274N	**Course Name**	Aerodynamics I Laboratory	**Course Category**	PC	L	T	P
						0	0	3

Pre-requisite Courses	Elementary mechanics	**Co-requisite Courses**	Aerodynamics, propulsion, Aircraft structures	**Progressive Courses**	Advanced aircraft design, Unmanned Aerial Vehicles
Course Offering Department		Aerospace Engineering and Applied Mechanics		**Data Book / Codes/Standards**	See learning Resources

Course Objective	This course equips students with practical skills in aerodynamic testing and analysis. Students will design and compare open and closed-circuit wind tunnels, calibrate airspeed sensors, and analyze propeller performance in various conditions. They will optimize motor-propeller combinations, visualize flow behavior using tufts, and measure airfoil geometry and pressure distribution. The course emphasizes applying aerodynamic principles to analyze and optimize systems, providing hands-on experience in wind tunnel operations and airfoil performance evaluation.

Module	**Syllabus**	**Classes**	**Outcome**
1	Introduction	4	Understand the fundamentals and objectives of aerodynamic experimentation.
2	Introduction to Wind Tunnels: Overview of open and closed-circuit wind tunnels, loss coefficient calculation, performance comparison, and identification of design defects.	5	Analyze wind tunnel types, calculate losses, and evaluate design limitations.
3	Calibration of Airspeed Sensor: Calibration of electronic differential pressure sensor and accurate measurement of airspeed.	5	Calibrate differential pressure sensors to accurately measure airspeed.
4	Propeller Testing at Zero Advance Ratio: Measurement of thrust coefficient, torque coefficient, and	5	Evaluate motor-propeller efficiency using thrust, torque, and figure of merit.

	figure of merit. Comparison and selection of optimal motor-propeller combinations based on efficiency.		
5	Propeller Testing in Forward Flight: Study of thrust and torque coefficient variation with advance ratio, propulsive efficiency, windmilling effects, and optimal motor-propeller selection.	5	Assess propeller performance with advance ratio and determine optimal setups.
6	Flow Visualization and Stall Characteristics: Quantitive and qualitative flow visualization , Investigation of flow separation and stall behavior in different airfoils using tuft-based flow visualization techniques. Image processing and Particle Image velocimetry (PIV)	5	Investigate flow separation and stall using tuft flow and PIV techniques.
7	Airfoil Geometry Measurement: Measurement of surface coordinates of an unknown airfoil to determine its shape and profile.	5	Measure airfoil surface coordinates to determine its geometry and profile.
8	Pressure Distribution on Airfoils/cylinder/ High lift devices: Measurement of Cp distribution at various angles of attack and Reynolds numbers using a pressure scanner and data acquisition system.	5	Analyze Cp distribution across various geometries under different conditions.
9	Makeup classes	3	Reinforce and clarify concepts through additional sessions.

Course Outcome	Upon completing this course, students will be able to design, analyze, and optimize various aerodynamic systems, including wind tunnels, propellers, and airfoils. They will understand the principles of wind tunnel operation, including loss coefficient calculation and performance comparison, and be able to identify design defects. Students will also be proficient in calibrating airspeed sensors and measuring thrust and torque coefficients, figure of merit, and propulsive efficiency in propeller testing. Additionally, they will be able to visualize and analyze flow separation and stall behavior in airfoils, measure pressure distribution, and determine airfoil geometry. These skills will enable students to select optimal motor-propeller combinations, design efficient aerodynamic systems, and conduct experiments to validate theoretical models

Learning Resources	• Instrumentation, Measurements, and Experiments in Fluids, Second Edition By Ethirajan Rathakrishnan • https://hackaday.io/project/5334-serialplot-realtime-plotting-software • https://www.aerodynamics4students.com/propulsion/blade-element-propeller-theory.php • https://makersportal.com/blog/2019/02/06/arduino-pitot-tube-wind-speed-theory-and-experiment. Note; (There are some mistakes in this tutorial DO-NOT COPY without attending instructions in the class) • https://www.nxp.com/docs/en/data-sheet/MPXV7002.pdf Other materials will be shared in class

5th Semester Courses Syllabi

B. Tech in Aerospace Engineering

Course Code	AE3101N	Course Name	Aircraft Dynamics Stability and Control	Course Category	PC	L	T	P
						3	1	0

Pre-requisite Courses	Aircraft Dynamics	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department		Aerospace Engineering & Applied Mechanics		Data Book / Codes/Standards	Nil

Course Objective	1. Understand static and dynamic stability, aerodynamic fundamentals, longitudinal and lateral stability, control surfaces and systems, stability derivatives, control systems design. 2. Understand how an aircraft's design impacts its stability and controllability 3. Understand static stability and trim; stability derivatives and characteristic longitudinal and lateral-directional motions; and physical effects of the wing, fuselage, and tail on aircraft motion. 4. Understand method of mathematical modelling of physical systems for various aircraft motions and related stability.

Module	Syllabus	Duration (class-hour)	Module Outcome
1	Introduction to Design Thinking in problem solving related to control system (promoting user-centered approach).	02	Understanding complex system dynamics, identifying hidden user needs, and fostering creativity in solution generation
2.	**Introduction:** Basic Terminologies of Control System; Transfer Function; Block Diagram; Open Loop and Closed Loop Transfer Function; State Space Analysis; procedural steps for solving physical systems through state variable approach; State Transition Matrix; Relationship between Transfer Function and State Space Equation	06	Provides a foundation for understanding and designing complex systems
3.	**Stability:** Introduction; The Characteristics Equation; The Routh-Hurwitz Stability Criterion; Time Domain Analysis; Frequency Response; Stability and relative stability using Root Locus approach; Bode Plot; Nyquist Stability Criterion. Problem solving. Problem solving.	07	Understanding of how to analyze the stability of control systems.

4.	**PID Controllers:** Response of First Order and Second Order Systems with Proportional (P), Derivative (D), Integral (I), PD, PI, PID Control. Problem solving.	04	Understanding how to improve system stability, reduce steady-state errors, and optimize transient responses
5.	**Optimal Control Design:** Linear Quadratic Regulator (LQR) Design. Problem solving.	04	Understanding of designing controllers for linear systems to minimize a quadratic cost function, improving system performance and reducing errors.
6.	**Linearized Longitudinal Dynamics:** Fundamentals of Dynamics – Eigenvalue Problems; Longitudinal Motion: The Linearized Coupled Equations; Short Period Approximation; Long Period Approximation; Pure Pitching Motion	05	Understanding of how an aircraft behaves in the longitudinal plane, particularly in terms of its stability and dynamic behavior under small perturbations.
7.	**Linearised Lateral dynamics:** Lateral Motion – The Linearised Coupled Equations; Roll Approximation; Spiral Approximation; Dutch Roll Approximation; Pure Rolling Motion; Pure Yawing Motion; Longitudinal-Lateral Coupling; Nonlinear Effects. Problem solving.	09	Understanding of how an aircraft moves sideways, particularly in terms of its rolling and yawing motions
8.	**Flying and Handling Qualities:** Introduction; Short Term Dynamic Models; Flying Qualities Requirements; Aircraft Role; Longitudinal Flying Qualities Requirements; Control Anticipation Parameter; Lateral Directional Flying Qualities Requirements; Flying Qualities Requirements on the s-Plane. Problem solving.	05	Design and analyze aircraft stability, control, and pilot-aircraft interaction
9.	**Stability Augmentation:** Introduction; Augmentation System Design; Closed Loop System Analysis; The Root Locus Plot; Longitudinal Stability Augmentation; Lateral-directional Stability Augmentation; The Pole Placement Method. Problem solving.	06	Improve the stability and control of an aircraft by enhancing flying qualities utilizing root locus analysis and pole placement methods
10.	**Aerodynamic Modeling:** Introduction; Quasi-static Derivatives; Derivative Estimation, The Effect of Compressibility; Limitation of Aerodynamic Modeling. Design thinking and problem solving.	04	Understanding of how to approximate the aerodynamic forces acting on an aircraft by analyzing its geometry, motion, and surrounding air flow, compressibility effects and dynamic situations.
11.	**Revision**	02	

Course Outcome	This course will also help in creating a background to design an airplane from stability and control aspects. Students will be able to describe and analyze aircraft stability and control, understand the contributions of various components to stability, and apply their knowledge to design and analyze control systems for aircraft. Students will be able to use software like MATLAB to generate and analyze control-system designs. Students develop a strong practical understanding of the stability and control

	principles of airplanes. Students develop valuable skills in problem-solving, critical thinking, and teamwork.

Learning Resources	**Books**: 1. Flight Stability and Automatic Control *by* Robert Nelson, McGraw Hill 2nd Edition 2. Aircraft Dynamics from Modeling to Simulation *by* Marcello R. Napolitano, John Wiley & Sons, Inc. 3. Aircraft Flight Dynamics and Automatic Flight Control *by* Part I & Part II by Jan Roskam, Darcorporation; Reprint edition (January 2001). 4. Mechanics of flight *by* Phillips, W.R. .2nd Edition John Wiley 2010. 5. Flight Dynamics Principles *by* M.V.Cook, John Wiley & Sons Inc. 6. Modern Control Engineering by Katsuhiko Ogata. 7. N. S. Nise: Control Systems Engineering, 4th Ed., Wiley, 2004.

Course Code	AE3102N	**Course Name**	Computational Fluid Dynamics	**Course Category**	PC	L	T	P
						3	0	0

Pre-requisite Courses	Fluid Mechanics, Compressible flow	**Co-requisite Courses**	NMCT,Programming Knowledge	**Progressive Courses**	NIL
Course Offering Department		Aerospace Engineering & Applied Mechanics		**Data Book / Codes/Standards**	NIL

Course Objective	The objective of CFD is to model the continuous fluids with Partial Differential Equations (PDEs) and discretize PDEs into an algebra problem (Taylor series), solve it, validate it and achieve simulation based design. The students will understand the process of developing a geometrical model of the flow, applying appropriate boundary conditions with flow equations, specifying different solution parameters, and finally post processing the numerical data to know the flow physics.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	Introduction of CFD, CFD- Application, CFD – Physics CFD –Modeling CFD – Process	04	Introduction
II	Difference Representations; Errors; Consistency; Stability; Convergence	06	Basics of Discretisation Methods
III	Wave Equation; Heat Equation; Laplace’s Equation; Burger’s Equations	08	Selected Model Equations
IV	Fundamental equations; Boundary layer Equations; Euler Equations; Transformation of Governing Equations	04	Governing Equations of Fluid Mechanics
V	Two-Dimensional Finite Volume Methods; Three-Dimensional Finite Volume Methods, Boundary Conditions	10	Finite-Volume Formulation
VI	Practical applications considering Euler Equations and Navier-Stokes equations;	06	Numerical Method Applications

VII	Grid Generations	04	Ideas over mesh generation

Course Outcome	Students learn geometrical and mathematical modelling by formulating governing equations with proper boundary conditions using CFD and compare CFD results with experimental and analytical results (if available). Understand practical aspects of computational modelling of flow domains and grid generation. Students will be familiar with different methods- FDM, FVM through this course. They are also able to apply CFD techniques to solve real-world engineering problems.
Learning Resources	1. Computational Fluid Mechanics and Heat Transfer: J. C. **Tennehill**, D. A. **Anderson**, R. H. **Pletcher**; Taylor and Francis 2. Introduction to Computational Fluid Dynamics: Pradip **Niyogi**, S. K. **Chakrabartty**, M. K. **Laha**; Pearson Education 3. Computational Fluid Dynamics – The Basics with Applications: J. D. **Anderson** Jr.; McGrawHill 4. Computational Gasdynamics: Culbert B. **Laney**: Cambridge University Press 5.Computational Fluid Flow and Heat Transfer; K. **Muralidhar** and T **Sundararajan**; Narosa Publishing House 6. Computational Fluid Dynamics: Principles And Applications; J. **Blazek**, Elsevier 7. Computational Fluid Dynamics, T. J. **Chung, Cambridge University Press**

Course Code	AE3103N	Course Name	Introduction to FEM and Applications	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	Aerospace Structures – I & II, Numerical Method and Computational Tools	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department		Aerospace Engineering & Applied Mechanics		Data Book / Codes/Standards	Nil

Course Objectives	To teach numerical approach of solution for various structural problems

Module	Syllabus	Duration (class-hour)	Module Outcome
I	Variational (Rayleigh-Ritz) approach – spring element and related numerical problems Pascal's triangle – strong and weak form of formulation – natural coordinates and shape functions for different cases – isoparametric, subparametric and superparametric element – bar, quadratic plane, hexahedral element, plane stress element – patch test, derivation of stiffness matrices, consistent loading, solution to various types of problems	18	Will learn the variational approach for FEM
II	Coordinate transformation – stress, strain, material properties, stiffness matrices	08	Will learn coordination transformation technique
III	Basic aspects of plate bending parameters – application of FEM in Kirchhoff and Mindlin theory	06	Will learn to apply FEM in plate bending problems
IV	Weighted residual (Collocation, Least Square, Sub-domain collocation, Galerkin) approach – derivation of basic equation using classical & FE form – example solution	10	Will learn the weighted residual approach for FEM

Course Outcome	• Will be capable to solve various aerospace structural problems using FEM • Will develop basic ideas how to correlate with FEM softwares.

Learning Resources	1. Introductory methods of numerical analysis, Sastry, PHI 2. Concepts and applications of finite element analysis, Cook et al., John Wiley & Sons

Course Code	AE3104N	Course Name	Composites and Structures	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	Strength of Materials	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department		Aerospace Engineering & Applied Mechanics		Data Book / Codes/Standards	Nil

Course Objectives	This subject helps to achieve fundamental knowledge on composite materials and their constituents, different manufacturing processes of composite products, basic fundamental formulae of different composite material properties, transformation of composite material properties from one frame to another frame, different types of laminate composites and their application in aerospace structures and other industries, different failure criteria of composite laminates, and design of composite laminates.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	Introduction to composite materials: Definitions; constituent materials; terminologies; general characteristics; advantages and uses	4	Familiar with composite materials, their constituents and their roles in strength of composites and practical applications.
II	Manufacturing processes of composite materials: Contact moulding methods; compression moulding methods and filament winding	5	Acquainted with different manufacturing processes of composite components/parts and merits and demerits of different processes.
III	Micromechanical analysis of composite strength and stiffness: Volume and weight fractions; longitudinal strength and stiffness; transverse modulus; inplane shear modulus and Poisson's ratio	6	Able to determine different strengths and moduli of composites from constituents' properties.
IV	Elastic properties of unidirectional lamina: stress-strain relationship; engineering constants; transformation of stress and strain; transformation of elastic constants; transformation of engineering constants	10	Able to determine different engineering constants at different frameworks for design of composite components.
V	Analysis of laminated composites: strain-displacement relationship; stress-strain relations; equilibrium equations; laminate stiffness; determination of lamina stresses and strains; types of laminate configurations	12	Familiar with different types of laminates, their merits and demerits and design of laminate structures.
VI	Failure theories and strength of a unidirectional lamina: Micromechanics of failure of unidirectional lamina; anisotropic strength and failure theories	5	Able to do failure analysis of composite components designed for different loading conditions.

Course Outcome	Students will be able to design and develop different structural parts made of composite materials and do failure analysis of FRP structures after completion of this course.

Learning Resources	1. Madhujit Mukhopadhyay, Mechanics of Composite Materials and Structures, Universities Press, 2004. 2. R. M. Jones, Mechanics of Composite Materials, McGraw Hill, 1993. 3. T. H. G. Megson, Aircraft Structures for Engineering Students, Butterworth Heinemann, 4^{th} Edition, 2007

Course Code	AM3161N	Course Name	Droplets and sprays	Course Category	OE2	L	T	P
						3	0	0

Pre-requisite Courses	Fluid Mechanics	Co-requisite Courses	Liquid rocket	Progressive Courses	Industrial combustion
Course Offering Department		Aerospace Engineering & Applied Mechanics		Data Book / Codes/Standards	

Course Objective	The objective of the course is to provide students with a thorough understanding of the fundamental principles for the formation of droplets, and physics of atomization and spray formation. After completion of course, students can design atomizer systems and their application in a wide variety of engineering branches, including spray drying, spray coating, spray cooling, fuel injection, etc. These fundamentals are followed by topics on diagnostics, drop/wall interactions and further advanced topics and applications.

Module	Syllabus	Duration (class-hrs)	Module Outcomes
1	**Introduction to Droplets**: Introduction to Droplets and Sprays, Application for Combustion and Propulsion, Surface Tension and lnternal Pressure, Charged Droplets, Small-Amplitude Droplet Oscillations, Internal Circulation, Instability of Droplets, Instability of Jets, Droplets Evaporation, Interaction with Surfaces, Role of Physical Properties, State, and Flow Regimes	8	Module will help in understanding the fundamental Principles of Droplet Formation and Dynamics. Students can analyse droplet behaviour in various systems, and can explore droplets applications in Science and Industry
2	**Atomization:** Fundamentals of Atomization, Atomizers and their applications, Atomizer performance Static Drop Formation, Stability of Liquid Jets and Sheets, dynamics of breakup of Drops, Breakup and Atomization Models, Secondary Breakup	6	Module will help to describe the physical mechanisms and energy balances involved in the disintegration of liquids into droplets. Students can classify and compare different atomization techniques.
3	**Spray:** Spray Formation, Spray Penetration, Spray properties, Spray cone angle, Vortex ring in sprays, drop size distribution in sprays, Circumferential Liquid Distribution, Drop-drag coefficients, Spray Size and Patternation Methods	10	Students can explain the physics of liquid breakup, droplet formation, and spray development under various flow conditions. Analyze spray characteristics and droplet distributions, conduct experimental analysis of atomized sprays.
4	**Evaporation and combustion of droplets and sprays:** Drop evaporation, Steady-State Evaporation, Unsteady-State Analysis, Drop Lifetime, Convective Effects on Evaporation, Calculation of Effective Evaporation Constant, Influence of Evaporation on Drop Size Distribution,	12	Module will describe the physics of droplet evaporation, analyse droplet combustion mechanisms, and describe spray combustion behaviours. Students can apply mathematical models to evaporation and combustion processes, which helps them to understand the role

	drop burning, Heating and Evaporation of Mono-component Droplets, Combustion of Mono-component Fuel Droplets, Multicomponent fuel drops, Combustion of Multi-component Fuel Droplets, Heating, Evaporation and Auto-ignition of Sprays		of droplet and spray parameters. Students can interpret experimental data on droplet/spray behaviours
5	**Miscellaneous applications:** Internal Combustion Engines, Fire Suppression, Spray Cooling, Fuel-Coolant Interaction in Nuclear Reactors, Medicine and Health, Bio-aerosols, Production of Small Solid Particles, Cloud Physics, Applications in Space, Droplets in a Microgravity Environment, Atomization of Alloy Powders, Ink-Jet Printing, Droplet-Based Manufacturing, Contact Angles and Wettability, Aerosols	6	Various important engineering applications of droplets will be covered theoretically and mathematically.

Course Outcome	• Explain the fundamental physics of droplet formation, breakup, and evaporation processes in various fluid environments. • Classify different spray types and atomization techniques based on application requirements and fluid properties. • Evaluate the effects of nozzle design, injection parameters, and ambient conditions on spray characteristics such as droplet size distribution, velocity, and penetration. • Apply knowledge of droplet and spray behavior to real-world applications in combustion systems, cooling technologies, pharmaceuticals, and agricultural sprays.

Learning Resources	4. Arnold Frohn and Norbert Roth, Dynamics of Droplets, Springer. 5. Sergei Sazhin, Droplets and Sprays, Springer 6. Arthur H. Lefebvre and Vincent G. McDonell, Atomization and Sprays, CRC Press

Course Code	AM3162N	Course Name	Materials Selection and Manufacturing Process	Course Category	OE2	L	T	P
						3	0	0

Pre-requisite Courses	Nil	Co-requisite Courses	None	Progressive Courses	Advanced Manufacturing Process
Course Offering Department		Aerospace Engineering and Applied Mechanics		Data Book / Codes/Standards	Nil

Course Objective	1. The primary objective of this course is to introduce the concept of manufacturing technology with the help of various casting processes widely employed in industries. 2. The course consists of welding and its classifications with the related details of equipment and applications. 3. To understand various metal forming, hot and cold working process. To appreciate the capabilities, advantages and the limitations of the processes. 4. To understand the various concepts of extrusion, forging processes, drawing, its classification and their applications. 5. To understand the various concepts of additive manufacturing and its advance techniques along with their applications.

Module	Syllabus	Duration (class-hour)	Module Outcomes
1	**Casting:** Pattern, Pattern materials, Pattern making, allowances of pattern and Pattern types., Casting process Types of casting: Continuous casting, Squeeze casting, vacuum mould casting, Evaporative pattern casting, ceramic shell casting, Casting defects., Molding process, Types of Molding process: Injection Molding, Blow molding.	10	By the end of this module, students will be able to: • Understand the purpose, types, and materials of patterns used in casting. • Analyze common casting defects, their causes, and preventive measures.
2	**Welding:** Introduction, Types of weld joints, Types of welding process: Gas welding, Arc welding, Electron beam Welding, Laser beam welding, Friction Stir Welding, Ultrasonic Welding, Thermite welding., Types of Arc welding process: Shielded metal arc welding, Submerged arc welding., welding defects – causes and remedies, Heat affected zones in welding.	8	By the end of this module, students will be able to: • Describe the fundamentals and significance of welding in manufacturing. • Classify weld joints and differentiate between various welding processes: gas, arc, electron beam, laser beam, friction stir, ultrasonic, and thermite welding.
3	**Extrusion and Forging:** Basic Extrusion process and types, forging operations and its classification., drawing: wire and tube drawing,	8	By the end of this module, students will be able to: • Explain the principles and classifications of extrusion and forging processes.

	Swaging, Blanking, Piercing, Punching and Trimming. **Cutting of Metals:** Oxy – Acetylene Gas cutting, Water Plasma Cutting, TIG cutting, MIG cutting, Soldering, Brazing.		• Understand and differentiate among metal cutting operations like swaging, blanking, piercing, punching, and trimming.
4	**Metal Forming:** Introduction, forming processes - Bending, Coining, embossing, rolling: types of Rolling and Roll mills, Strain Hardening, Recovery, Recrystallization and Grain growth **Advanced Metal Forming Process:** Details of High energy rate forming process, Electro Magnetic Forming, Explosive Forming, Electro-Hydraulic Forming, Contour Roll forming.	10	By the end of this module, students will be able to: • Compare metal cutting techniques: Oxy-Acetylene Gas cutting, Water Plasma Cutting, TIG, MIG, and advanced thermal cutting methods. • Describe various forming processes such as bending, coining, embossing, and rolling, and classify types of rolling and roll mills.
5	**Additive manufacturing:** Introduction to Rapid Prototyping, material, applications, limitations., **Techniques:** Photo polymerization, Stereo lithography, Powder Bed Fusion, Selective Laser Sintering, 3D Printing, Laminated Object Manufacturing.	6	By the end of this module, students will be able to: • Understand the principles of high-energy rate forming (HERF) methods including electromagnetic, explosive, electro-hydraulic, and contour roll forming.

Course Outcome	Upon completing this course, students will be able to: 1. Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems. 2. Acquire knowledge and hands-on competence in applying the concepts of manufacturing science in the design and development of mechanical systems. 3. Competence to design a system, component or process to meet societal needs within realistic constraints. 4. Demonstrate creativeness in designing new systems components and processes in the field of engineering in general and mechanical engineering in particular. 5. An ability to formulate solve complex engineering problem using modern engineering and information Technology tools.

Learning Resources	**Books:** 1. Manufacturing Technology, P.N. Rao, TMH 2. Manufacturing Technology, Kalpak Jain, Pearson education. 3. Production Technology, R.K. Jain **Reference Books:** 1. Principles of Metal Castings, Rosenthal. 2. Welding Process, Parmar 3. Manufacturing Technology, R.K. Rajput, Laxmi Pub 4. Manufacturing Engineering &Technology, Kalpak Jain, S.

Course Code	AM3163N	Course Name	Avionics and Navigation	Course Category	OE2	L	T	P
						3	0	0

Pre-requisite Courses	Basic knowledge of aircraft systems, control systems, and sensors	**Co-requisite Courses**	Aircraft Systems	**Progressive Courses**	• Unmanned Aerial Systems (UAS) Design • Advanced Flight Control Systems
Course Offering Department		Aerospace Engineering and Applied Mechanics		**Data Book / Codes/Standards**	• MIL-STD-1553 (Avionics Serial Data Bus Standard) • ARINC 429 and ARINC 664 (Avionics Data Bus Standards) • Navigation and GPS System Performance Standards (e.g., RTCA DO-229) • Human Factors Engineering Standards in Avionics (e.g., MIL-STD-1472)

Course Objective	This course aims to provide a comprehensive introduction to avionics systems in modern civil and military aircraft. Students will gain insights into cockpit display technologies, navigation systems, inertial and air data sensing, digital fly-by-wire control, and system integration strategies. The course also introduces emerging avionics in UAVs and automation systems.

Module	Syllabus	Duration (class-hour)	Module Outcome
1	Introduction to Avionics: Importance and role of avionics, Avionics system hierarchy and classification, and Overview of system functionalities and categories	06	• Understand the importance and role of avionics in modern aircraft systems. • Describe avionics system hierarchy, classification, and key functionalities.
2	Displays and Human-Machine Interaction: HUDs, HMDs, Head Down Displays, Display symbology, data fusion, Display management, tactile/audio inputs, eye tracking.	05	• Explain different types of aircraft displays and their symbology. • Understand human-machine interaction concepts including data fusion, input methods, and eye tracking.
3	Fly-By-Wire Flight Control Systems Principles and architecture of fly-by-wire systems, Control laws: pitch/roll rate control, PIOs, Overview of handling qualities and basic modern control concepts.	06	• Understand the principles and architecture of fly-by-wire flight control systems. • Explain control laws, handling qualities, and basic modern control concepts in flight control.
4	Inertial Sensors and Attitude Derivation Overview of inertial sensors and their role in aircraft navigation and control	10	• Understand the operation of inertial sensors and their role in aircraft navigation and control.

	systems, Principles of operation of gyroscopes (mechanical, MEMS, and optical) and accelerometers, Introduction to strap-down inertial systems and sensor alignment in the aircraft body frame, Basic attitude derivation methods using gyros and accelerometers: Euler angles, quaternions, and DCM.		• Explain basic attitude derivation methods using gyroscopes and accelerometers.
5	Navigation and Air Data Systems Navigation techniques: INS, GPS, AHRS, Sensor fusion and Kalman filtering, Air data laws: pressure, Mach number, true airspeed, Air data sensor types and computations.	10	• Understand key navigation techniques including INS, GPS, AHRS, and sensor fusion using Kalman filtering. • Explain air data systems, sensor types, and computations for pressure, Mach number, and true airspeed.
6	Avionics System Integration and UAVs Data buses: MIL-STD-1553, ARINC 429, integrated modular avionics (IMA), Use of COTS components and modular design, UAV avionics: architecture, sensors, control, and communication systems.	05	• Explain avionics data buses, modular design, and the use of COTS components in system integration. • Understand UAV avionics architecture, including sensors, control, and communication systems.

Course Outcome	By the end of the course, students will be able to: 8. Explain the structure, function, and role of major avionics systems. 9. Analyze pilot interface systems including HUD, HMD, and modern display technologies. 10. Understand fly-by-wire control system architecture and control law implementation. 11. Evaluate inertial sensors and compute attitude using strap-down algorithms. 12. Understand navigation aids and air data measurement principles. 13. Comprehend avionics system integration frameworks and UAV-specific avionics.

Learning Resources	**Textbooks:** 1. Introduction to Avionics Systems by R.P.G. Collinson, Springer, 3rd Edition 2. Introduction to Avionics – *Rick S. Brown & Dale R. Cundy* 3. Avionic Systems Design John R. Newport

Course Code	AM3164N	Course Name	Mechatronics	Course Category	OE2	L	T	P
						3	0	0

Pre-requisite Courses	Nil	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department		Aerospace Engineering and Applied Mechanics		Data Book / Codes/Standards	Nil

Course Objectives	1. To understand synergistic integration of mechanical engineering, electronics, control engineering, and computers, all integrated through the design process. 2. To involve the application of complex decision making to the operation of physical systems. 3. To develop systematic frameworks and modular, hierarchical architectures for the concurrent, detail-level engineering of simple systems, from conception to configuration to integration to realization and implementation, by using the expert's knowledge base through the object-oriented hardware-in-the-loop simulations. 4. To create genuine interest and ability across a wide range of technologies which will provide the most economic, elegant and appropriate solution to the problem in hand. 5. To identify, formulate and solve complex engineering problems by applying principles of engineering, science and mathematics

Module	Syllabus	Duration (class-hour)	Module Outcome
I	**Mechatronics:** What is Mechatronics? Mechatronics Systems, Measurement systems, Control systems, Microprocessor-based controllers, response of systems, Mechatronics approach. **Critical thinking and problem solving**	3	• Identification of key elements of mechatronics system and its representation in terms of block diagram.
2	**Basic system models:** Mathematical models, Mechanical system building blocks, Electrical system building blocks, Fluid system building blocks, Thermal system building blocks and Multidisciplinary Physical Systems	5	• Mechatronics system modeling involving interdisciplinary knowhow.
3	**Concept of mechanism** (link, joints, DOFs, 4 bar, crank-connecting rod)) and basic mechanical elements for motion transmission (gear, belt), **:** Mechanical systems, Types of motion, kinematic chains, Cams, Gear trains, rachet and pawl, Belt, chain drives, bearings.	4	• Understanding of mechanical motion transmission system
4	**Pneumatic, hydraulic and electrical actuation systems:** Actuation systems, Pneumatic and hydraulic systems, Directional control valves, Pressure control valves, Cylinders, Process control valves, Rotary actuators. **Electrical actuation systems:** Electrical systems, Mechanical switches, D.C. motors, A.C. motors, Stepper motors.	5	• Outline the various types of actuators to implement in mechatronic systems.
5	**Sensors and transducers:** Sensors and transducers, Performance terminology,	5	• Understand principles of sensors, its characteristics,

	Displacement, position and Proximity, Force, Fluid Pressure, Liquid Flow, Liquid level, Selection of sensors.		
6	**Signal conditioning:** Signal conditioning, The Operational amplifier, Wheatstone bridge, Digital signals, Data acquisition, Digital Signal Processing.	3	• Sensor interfacing with DAQ microcontroller
7	**System models:** Engineering Systems, Rotational–translational systems, Electromechanical Systems, Hydraulic mechanical systems. **Dynamic responses of systems:** Modeling dynamic systems, First-order systems, Second-order systems. **System transfer functions:** The transfer function, First-order systems, Second-order systems. **Frequency response:** Sinusoidal input, Frequency response, Bode plots. **Closed-loop controllers:** Continuous and discrete control processes, Control modes, Proportional mode, Derivative control, Integral control, PID controller, Adaptive control.	6	• Analyze the role of control, modelling and stability of mechatronics system. • Time and Frequency domain analysis of system model (for control application) • PID control implementation on real time systems
8	**Microprocessors:** Microprocessor systems, Microcontrollers, Applications. **Input/output systems:** Interfacing, Input/output addressing, Serial communications interface, Examples of interfacing. **Introduction to embedded systems** **Programmable logic controllers:** Programmable logic controller, programming.	4	• Describe the principle and functioning of microprocessor and microcontroller • Development of PLC ladder programming and implementation of real-life system.
9	**Communication systems:** Digital communications. **Human Computer Interaction**, Virtual Instruments, Man Machine interface, Virtual Reality	3	• Understanding Man-machine interface
10	**Mechatronics systems:** Traditional and Mechatronics designs, Possible Mechatronics design solutions, Case studies of mechatronic systems. **Future Trends, Applications -** Autotronics, Bio-mechatronics	4	• Understanding different examples of mechatronics system design and prototype development.
	Total class	42	

Course Outcome	Students should be able to: 1. Create products, systems, machines, installations, or industrial processes by integrating mechanical, electronic, and automation tools and functions. 2. Design mechatronics system solutions. 3. Practice ethical conduct and professional responsibilities in Mechatronics environments.

	4. Formulate engineering solutions by considering their global, economic, societal, and environmental impact.

Learning Resources	1. Mechatronics - by W. Bolton (Pearson) 2. Mechatronics - An Introduction by Robert H. Bishop (Taylor & Francis) 3. Mechatronics System Design - by Shetty and Kolk (Cengage) 4. Mechatronics - An Integrated Approach by Clarence W. de Silva (CRC Press)

Course Code	AE3171N	Course Name	Aircraft Dynamics Stability and Control Laboratory	Course Category	PC	L	T	P
						0	0	3

Pre-requisite Courses	Nil	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department		Aerospace Engineering & Applied Mechanics		Data Book / Codes/Standards	*Nil*

Course Objective	
	1. Provide hands-on experience with the principles of aircraft stability and control. 2. Improved knowledge and skills to understand and apply stability and control concepts in real-world scenarios. 3. Understand how an aircraft's design impacts its stability and controllability

Module	Syllabus	Duration (class-hour)	Module Outcome
1	Introduction to Design Thinking in problem solving for aircraft control. Familiarization with MATLAB/SIMULINK for the following Control System Engineering. Step Response, Impulse Response, Ramp Response of Transfer Function. Root Locus, Bode Plot and Nyquist Plot from Transfer Function. Step, Impulse and Ramp Response of State Model. P, I, PI, PD, PID Controller, Basic Concepts, Simulation.	06	• Proficiency in using MATLAB/Simulink to analyze system responses
	SRV02: A. SRV02 Modeling: Deriving the dynamic equation and transfer function for SRV02 servo plant using the first-principles B. Frequency Response Experiment C. Experiment with Step Input Model Validation Experiment	06	• Transfer function for servo motor plant
	SRV02 Position Control Experiment	03	• Servo position control
	SRV02 Speed Control Experiment	03	• Servo speed control
	Rotary Pendulum: Modeling and Experiment A. Experiment with Balance Control B. Experiment with Swing-up Control	03	• Experiment with Swing-up Control
	Rotary Double Inverted **Pendulum:** Mode1ing, Simu1ation and Experiment	03	• Stability properties
	Rotary Flexible **Link:** Modeling, Simulation and Experiment	03	• Control of two-degree of freedom system
	Experiment with Rotary Gyroscope	03	• Design controller
	Experiment with Aero-2DOF Dual Rotor System: Simulation and Experiment with A. PD Control B. State Feedback Control with LQR and Kalman Filter	03	• Comprehensive understanding and practical application of control systems for a complex, nonlinear, and coupled system like a 2-DOF helicopter

	Experiment with Half-Quadrotor: Simulation and Experiment with A. PD Control B. State Feedback Control with LQR and Kalman Filter	03	• Demonstrate control strategies for a quadrotor platform
	Development of Complete Aircraft System Model and Evaluate Static and Dynamic Stability of the Aircraft. Project on Aircraft Longitudinal Stability and Control involving critical thinking.	03	• Comprehensive understanding of aircraft stability and control principles
	End Test and Viva voce	03	• Performance evaluation

Course Outcome	1. Students will be able to develop a strong practical understanding of the stability and control principles of airplanes. 2. Students will develop valuable skills in problem-solving, critical thinking, and teamwork.

Learning Resources	1. Laboratory Manual 2. Book: Ogata, K., Modem Control Engineering, 4th Ed. Prentice Hall India, 2006. 3. User Manuals of the various experimental setups of M/s. Quanser Inc.

Course Code	AE3172N	Course Name	Mathematical Modelling and Simulation Laboratory	Course Category	PC	L	T	P
						0	0	3

Pre-requisite Courses	Computer Programming and Higher Mathematics	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department		Aerospace Engineering & Applied Mechanics		Data Book / Codes/Standards	Matlab / Simulink / C and C Graphics

Course Objective	1. Develop a mathematical model of real-world problems, which is a concise way of describing the various factors affecting the system, build and analyze models, and use simulations to understand complex systems. 2. Develop numerical solutions of linear and non-linear algebraic equations, ordinary differential equations and partial differential equations; 3. Solve problems related to Aerospace Engineering using software tools (Matlab / Simulink).

Module	Syllabus	Duration (class-hour)	Module Outcome
1	1. Introduction to MATLAB, Simulink, C and C Graphics 2. Elementary operations in Matlab: Matrix addition, subtraction, multiplication etc. 3. Introduction to Design Thinking in problem solving during engineering analysis (enhances problem-solving skills and fosters a deeper appreciation of mathematics as a dynamic and creative field)	6	• Foundational knowledge in MATLAB, Simulink, C, C++ programming and Design Thinking
	4. Solving a Second-Order ODE Using MATLAB/Simulink	3	• Solve Differential Equation using programming
	5. Free Vibrations of Spring-Mass-Damper Systems (overdamped, under-damped and critically damped) 6. Bouncing Ball Response with Negligible Drag	6	• Dynamic mechanical system modelling
	7. Capacitor Discharge Response (A First-order System)	3	• Study the differential equation to describe capacitor discharge in an RC circuit
	8. Linked Mechanism Analysis (Modelling and motion simulation of the crank-connecting rod and four bar mechanism) 9. Simulation of forward and inverse kinematics of 2 link planer manipulator in Matlab	6	• Developing a strong understanding of kinematic analysis

	10. Response of a Particle in Projectile Motion with Air Drag (Simulation of motion of free fall with air resistance parachute) 11. Simulation of Inverted Pendulum in Simulink	6	• Understand the system's dynamics, instability, and how control systems can be used to stabilize it.
	12. Modelling and simulation of deflection of beam (Euler-Bernoulli) under different loading condition	3	• Ability to analyze and predict the behavior of beams under various loads
	13. Image processing and edge detection in MATLAB 14. Red colour object detection and position tracking	3	• Fundamental of image processing using mathematics
	15. 3D modelling and Simulation in Virtual Reality Environment (Dynamics of bouncing ball) 16. Apply design thinking during modelling and simulation for engineering analysis	3	• Understanding virtual reality and design thinking
	End Test and viva examination	3	• Performance evaluation

Course Outcome	• Students will be able to apply mathematical concepts to real-world problems, build and analyse models, and use simulations to understand complex engineering systems involving interdisciplinary knowledge. • They will develop analytical skills for problem solving using mathematical tools. Students will have a deeper understanding of the engineering system being modelled and will be able to make informed decisions based on the simulation results and data analysis. • By seeing the "how" and "why" unfold, students gain a clearer understanding and replicate the process with greater confidence.

Learning Resources	MMS Lab Manual MATLAB for Engineers by Holly Moore MATLAB by Rudra Pratap Simulink: Dynamic System Simulation for MATLAB by MathWorks

Course Code	AE3173N	Course Name	Propulsion laboratory	Course Category	PC	L	T	P
						0	0	3

Pre-requisite Courses	Heat Transfer	Co-requisite Courses	Aircraft Propulsion	Progressive Courses	Nil
Course Offering Department		Aerospace Engineering & Applied Mechanics		Data Book / Codes/Standards	Nil

Course Objective	The objective of the Propulsion Laboratory course is to provide students with practical, hands-on experience in the principles and applications of aerospace propulsion systems. Through a series of experiments and demonstrations, students will develop a deep understanding of the performance, operation, and characteristics of various propulsion technologies. The course emphasizes data acquisition, analysis, and interpretation, as well as the application of theoretical concepts to real-world propulsion systems.

Module	Name of Experiments	Duration (class-hrs)	Module Outcomes
1	Introduction and Visit to lab	6	Brief introduction about lab, safety protocols, and theory/calculations for different experiments.
2	Performance studies of lab-scale subsonic ramjet engine	6	Working demo of lab-scale subsonic ramjet engine will be performed. Students will be able to calculate efficiencies and various performance parameters.
3	Propeller blade theory and measurement of propeller lift force	6	Students will observe and calculate how figure of merit (FOM) of propeller blades vary with changes in blade orientation.
4	Performance studies of a duct burner	3	Students will calculate thermal efficiency of a lab-scale duct burner by noting down different variables.
5	Laminar flame speed studies in a hollow cylindrical pipe	3	Students will observe how the changes in air/fuel (A/F) ratio will affect the velocity of premixed flame.
6	Flame characterization studies: Diffusion to premixed flame using flame stabilization set-up	3	Students will observe how the changes in A/F ratio affect the flame length and flame characteristics for premixed and diffusion flames.
7	Determination of heat of combustion using bomb calorimeter	3	Students will calculate heat of combustion values of given unknown three types of solid/liquid fuels
8	Flame analysis of ramjet, duct burner, and flame stabilization unit using UV-Vis-Spectrometer	3	With the help of UV-Vis-Spectrometer, students will observe and understand how the flame species will change for ramjet, duct burner, and flame stabilization with the change in A/F ratio.
	End-test	3	
	Viva Voce	3	

Course Outcome	• Demonstrate the ability to conduct experiments on propulsion systems and analyze the resulting data. • Evaluate the performance characteristics (e.g., thrust, specific fuel consumption, efficiency) of various propulsion systems through experimental methods. • Apply theoretical knowledge of thermodynamics and fluid mechanics to interpret experimental results and validate propulsion models. • Use appropriate instrumentation and data acquisition systems to measure propulsion system parameters accurately. • Identify sources of error in experimental setups and suggest methods for improving accuracy and reliability.

Course Code	AE3174N	Course Name	Computational Fluid Dynamics Laboratory	Course Category	PC	L	T	P
						0	0	3

Pre-requisite Courses	Fluid Dynamics, Aerodynamics	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department		Aerospace Engineering & Applied Mechanics		Data Book / Codes/Standards	Nil

Course Objective	The objective of this course is to equip students with practical skills in Computational Fluid Dynamics (CFD) through hands-on experience using industry-standard software for solving aerospace flow problems. Students will learn the complete CFD workflow, including geometry creation, mesh generation, setting up physical models and boundary conditions, solving, and post-processing of results. Emphasis will be placed on analyzing and interpreting simulation data to make informed engineering decisions in aerospace applications. Additionally, students will be trained to validate their CFD simulations by comparing numerical results with analytical or experimental data to ensure the accuracy and credibility of their computational models.

Module	Name of Experiments	Duration (class-hrs)	Module Outcomes
1	Introduction to CFD software and Workflow	3	Understand the full CFD process including geometry, mesh generation, solver setup, and result visualization.
2	Laminar Flow Over a Flat Plate	3	Learn to compute boundary layer thickness, velocity profiles, and compare with Blasius analytical solution.
3	2D Flow Over a NACA 0012 Airfoil	3	Visualize lift and pressure coefficient distribution; identify separation zones and compare lift/drag with theory.
4	Subsonic Flow Through a Converging Nozzle	3	Analyze velocity and pressure variations; understand subsonic compressible flow behavior.
5	Supersonic Flow in a Converging-Diverging Nozzle	3	Capture shock locations; observe flow choking and Mach number variation in supersonic regimes.
6	Flow Over a Cylinder (Steady/Unsteady)	3	Study vortex shedding, compute drag coefficient, and understand flow-induced oscillations.
7	Turbulent Flow with k-ε and k-ω SST Models	3	Compare turbulence models; assess boundary layer prediction and separation behavior.
8	Supersonic Flow Over a Wedge	3	Visualize oblique shock waves and expansion fans; calculate pressure ratios across shocks.
9	Internal Duct Flow with Heat Transfer	3	Simulate convective heat transfer in a duct; analyze temperature profiles and compute Nusselt number.

10	Jet Exhaust Simulation (Axisymmetric/3D)	3	Model a jet plume; study shear layer, temperature distribution, and thrust calculation.
11	Mini Project		Carry out an independent CFD simulation on an aerospace topic; present technical report and oral presentation.
	End-test and Viva Voce	3	

Course Outcome	• Apply CFD methods to simulate real-world aerospace fluid flow problems using industry-standard software. • Select appropriate physical models, boundary conditions, and solver settings for various flow regimes. • Analyze simulation results to extract performance parameters such as lift, drag, shock location, and heat transfer. • Perform grid independence studies and validate simulation results with theoretical or experimental data. • Effectively communicate technical results through reports and presentations.

Learning Resources	1. Fluent, A. N. S. Y. S. "Ansys fluent theory guide." *Ansys Inc., USA* 15317 (2011): 724-746. 2. Ansys® Fluent®, release, Tutorial Guide, Ansys, Inc. 2020.

6th Semester Courses Syllabi

B. Tech in Aerospace Engineering

Course Code	AE3201N	Course Name	Aerodynamics II	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	Elementary knowledge of low speed aerodynamics	Co-requisite Courses	Engineering thermodynamics, Coding Knowledge	Progressive Courses	NIL
Course Offering Department		Aerospace Engineering & Applied Mechanics		Data Book / Codes/Standards	NIL

Course Objective	Students will understand fundamentals of compressible flow physics. Students will learn about wave phenomena, shock waves, shock-shock interactions, shock wave reflections, diffractions and expansion waves and its interaction with shock waves. The course aims to develop the ability to apply these concepts to design and analyze various aspects of high speed vehicles.

Module	Syllabus	Duration (class-hour)	Module Outcomes
I	One Dimensional Flow revisited; Hugoniot Equations; One Dimensional Flow with Heat Transfer; One Dimensional Flow with Friction. Problems.	06	• Introduction, Basic ideas over governing equations of compressible flows and its parameters
II	Two Dimensional Flow revisited; Shock Polar; Shock Reflection and Intersection; Bow Shock in front of a Blunt Body; Three Dimensional Shock Waves; Prandtl-Meyer Expansion Waves; Shock-Expansion Theory. Problems.	08	• Effects of Shock and Expansion waves on aerodynamic characteristics.
III	Quasi-One Dimensional Flow revisited; Nozzles; Diffusers. Problems.	06	• Quasi-1D flows- useful to aircraft and rocket nozzle
IV	Introduction; Moving Normal Shock Waves; Reflected Shock Waves; Elements of Acoustic Theory; Finite Waves; Incident and Reflected Expansion Waves; Shock tube Relations; Finite Compression Waves.	08	• Unsteady waves
V	Differential Conservation equations for Inviscid Flow; Crocco's Theorem; Velocity Potential Equation: Linearised Velocity Potential Equation; Linearised Subsonic Flow; Linearised Supersonic Flow; Method of Characteristics.	06	• Ideas over linearized supersonic flows
VI	Cones at Angle of Attack; Blunt Bodies at Angle of attack.	04	• Ideas over axisymmetric and 3D flows
VII	Steady and Unsteady Supersonic Flow- computational aspects	04	• Basic ideas over computational high speed flows

Course Outcome	Students will be able to explain the principles of compressible flow physics and shock dynamics. Students will be able to apply their knowledge to design and analyze different internal flows like nozzle, aircraft engine duct as well as over external aerodynamics of supersonic vehicles.

Learning Resources	• J. D. **Anderson** Jr., Modern Compressible Flow with Historical Perspective, McGraw Hill • A H **Shapiro**, Dynamics and Thermodynamics of Compressible Fluid Flow-Volume I& II, Ronald Press • H W **Liepmann** and A **Roshko**,Elements of Gas Dynamics, John Wiley & Sons • B. K. **Hodge** and C. **Koenig**, Compressible Fluid Dynamics (with P.C. applications),Prentice Hall, 1995. • S.M **Yahya**, Compressible Flows, New Age International Publisher.

Course Code	AE3202N	Course Name	Jet and Rocket Propulsion	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	Thermodynamics, Physics	Co-requisite Courses	Advanced propulsion	Progressive Courses	Nil
Course Offering Department		Aerospace Engineering & Applied Mechanics		Data Book / Codes/Standards	Nil

Course Objective	The objective of Jet and Rocket Propulsion is to introduce student's with Fundamental Concepts of Propulsion Systems and to explain Thermodynamic and Fluid Dynamic Principles. The courses will help students to **e**xplore Rocket Propulsion Fundamentals and to evaluate Propulsion System Performance**.** The course will **i**ntroduce Design and Integration Concepts with highlights on applications and modern rockets.

Module	Syllabus	Duration (class-hrs)	Module Outcomes
1	**Introduction:** Brief history of rocketry, classification of rocket propulsion systems, Rocket principle and rocket thrust equation, desirable parameters of a rocket, propulsive efficiency of rocket, multistage and clustering of rockets, Ideal Rocket Nozzle, Rocket nozzle design and its performance	10	Module will describe the fundamental principles of rocketry**.** Students will able to apply basic equations of rocket motion and propulsion**.**
2	**Chemical propellants:** Propellants and their types, ingredients of propellants, Physical and chemical properties of propellants, Combustion and Thermochemistry of propellants, Selection criteria of propellants, Numerical	6	Module will focus on thermo chemistry of rocket propellants. Students will able to select best propellant combinations for any rockets.
3	**Solid Rockets:** Working principle of solid rockets, Components of solid rockets, Propellant grain, Evolution of burning surface of propellant grain, burning mechanism Igniter, Ignition process in solid propellant grain, Physical process and burning mechanism of solid propellant burning, Measurement of burning rate and its governing factors, Choice of "n" for stable solid rocket operation, Propellant stress and strain, Efficiencies, Numerical	9	Module focus to understand the principles of solid rocket propulsion. Students can analyze the performance characteristics, design and evaluate solid rocket motors working. Students can also predict rocket behavior for different flight conditions.
4	**Liquid and Hybrid rockets:** Working principle of liquid and hybrid rockets, classifications, properties, Combustion mechanism, Components of liquid and hybrid rockets, Droplet evaporation and combustion in various environments, Numerical on designing of liquid and hybrid rockets	8	Module covers the fundamentals of liquid and hybrid propulsion systems. Students can analyze thermodynamics and fluid mechanics in rocket engines, can design and evaluate liquid propulsion components. Module also focuses to understand and apply hybrid rocket design.

5	**Combustion Instability:** Reasons for combustion instability, types of instability: Bulk and Wave mode, Mathematical solutions to different types of instabilities, Control of instabilities	6	Fundamental mechanisms of combustion instability will be covered in the module**.** Module will explain the physical and chemical processes leading to combustion instability in rocket engines. Students can classify and analyze types of instabilities.
6	**Advanced Rockets:** Classifications of advanced rockets, Working principle, electrical rockets: electrostatic, electrothermal, electromagnetic, Hall effect thruster, nuclear rockets, photon rockets, solar rockets, Numerical	3	Module will explain the working principles and design features of advanced propulsion systems including electric, nuclear thermal, photon based rocket engines.

Course Outcomes	• Students can explain the Principles of Propulsion Systems. • Analyse Performance Parameter • Classify and Compare Propulsion Systems • Apply Thermodynamic and Fluid Mechanics Principles • Design and Optimization of Propulsion Systems and to evaluate Environmental and Operational Constraint for rocket working.

Learning Resources	1. G. W. Sutton, Rocket Propulsion Elements, John Wiley and Sons 2. Rocket and Spacecraft Propulsion, M. J. L. Turner, Springer Praxis Publishing 3. Travis S. Taylor, Introduction to Rocket Science and Engineering, CRC Press 4. K RamamurthI, Rocket Propulsion, Macmillan

Course Code	AE3203N	Course Name	Aerospace Structure II	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	Preliminary knowledge of strength of materials	Co-requisite Courses	None	Progressive Courses	Course on Aircraft Design
Course Offering Department		Aerospace Engineering and Applied Mechanics		**Data Book / Codes/Standards**	None

Course Objective	The purpose of this course is to teach the principles of solid mechanics under bending, shear and torsional loading applied to thin-walled light weight structure. These principles can be used to design and analyze aircraft structural components under airframe loading and fatigue loading, considering airworthiness criteria.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	**Flight Vehicle Structures and Materials:** Structural components of aircraft and their functions – aircraft materials – strength-weight comparisons of materials – theories of failures – Airy's stress function and its applications	6	Students will learn about aircraft components and its material composition along with failure theories.
II	**Airframe Loads:** Airworthiness requirements – load factors – limit loads – ultimate loads – reserve factor and margin of safety – basic flight loading conditions – V-n diagram – fail-safe and safe-life approach – aircraft fatigue life – inertia loads analysis – analysis of maneuver loads (including acceleration) – analysis of gust loads	10	Students will be able to find out basic flight loading including inertia during landing, steady flight & maneuver. They will also be able to calculate change in load factor under gust loading.
III	**Unsymmetrical Bending: Analysis of Open & Closed Section Beam** Unsymmetrical bending – bending approximation for thin-walled section – stress-strain-displacement relation for open & closed thin-walled beam – deflection of unsymmetrical beam	8	Students will be able to find out bending stress distribution on thin walled open & closed section beams under unsymmetrical bending along with finding out its deflection.

IV	**Shear Flow: Analysis of Open & Closed Section Beam** Shear flow, shear centre & applications – shear of open section beam – shear of closed section beam	5	Students will be able to find out shear flow distribution on thin walled open & closed section beams under shear loading along with finding out its shear center.
V	**Torsion: Analysis of Open & Closed Section Beam:** Torsion of closed section beam – torsion of open section beam	4	Students will be able to calculate the rate of twist and warping distribution on thin walled open & closed section beams under torsional loading along with finding out its shear stresses.
VI	**Analysis of Combined Open & Closed section Beam under Shear & Torsional Loading**	3	Students will be able to find out shear flow distribution and optimum shear stress for Combined Open & Closed section beams.
VII	**Structural idealization** Idealization of a panel – effect of idealization for open and closed section beams: bending, shear, and torsion	6	Students will be able to idealize stringers by booms and calculate its equivalent effects, such as stress on booms & shear on skins.

Course Outcome	• Grasp the fundamental behavior of symmetrical and unsymmetrical thin-walled aircraft components under bending and shear loading and understand the concepts of shear flow and shear center. • Evaluate torsional warping and shear stresses in both closed and open sections. • Apply the concept of structural idealization for stress analysis of open and closed section beams, including single and multi-cell configurations. • Evaluate inertia load, airframe load under steady flight condition and gust load condition.

Learning Resources	1. Aircraft Structures for Engineering Students – T.H.G. Megson 2. Aircraft Structures – D. J. Peery and J.J. Azar 3. Mechanics of Aircraft Structures – C. T. Sun 4. Analysis and Design of Flight Structures – E.F. Bruhn

Course Code	AM3261N	Course Name	Industrial Combustion	Course Category	OE3	L	T	P
						3	0	0

Pre-requisite Courses	Thermodynamics, Fluid Mechanics, Heat transfer	Co-requisite Courses	Fundamentals of combustion	Progressive Courses	Nil
Course Offering Department		Aerospace Engineering & Applied Mechanics		Data Book / Codes/Standards	Nil

Course Objective	The objective of Industrial combustion is to provide students with a thorough understanding of Fundamental Combustion Principles applied in industries. It helps students to analyze Combustion Systems, to assess Fuel Types and Characteristics, to design and Optimization of Combustion Equipment. The course also helps in understanding Emissions and Environmental Impact, and to Apply Diagnostic and Measurement Techniques.

Module	Syllabus	Duration (class-hrs)	Module Outcomes
1	**Introduction:** Combustion process, Types of Fuels and Their Characteristics, Modes of Combustion Processes, Emissions and Environment, Combustion Thermodynamics, Combustion Stoichiometry, First Law Applied to Combustion, Standard Enthalpy, Standard Heat of Reaction, Adiabatic Flame Temperature, Second Law Applied to Combustion, heat transfer and combustion	8	Module will help students to understand the fundamentals of industrial combustion, to analyze combustion equipment and systems. Thermodynamics of combustion will also be covered.
2	**Combustion system components:** Burners, burner types, design factors, Combustors, combustor classifications, Design considerations, Heat load, Heat recovery devices, Injectors, types of injectors, Injector design, Oxygen Enrichment methods, Electrical Equipment and Wiring	8	Module will help to identify and describe key components in industrial combustion systems, understand the integration of components into complete combustion systems. Students can apply heat transfer and fluid mechanics in component design.
3	**Flame impingement:** Experimental Conditions, Configurations, Operating conditions, Stagnation targets, Measurements, Laminar and turbulent flow, heat transfer co-relations, Flames Impinging Normal to a Plane Surface, Flames Parallel to a Plane Surface	8	Module will help students to explain the physical and chemical processes involved when a flame interacts with a solid surface, including heat transfer, flame structure alteration, and material response. Students can evaluate convective and radiative heat fluxes during flame impingement and

			their impact on surface heating.
4	**Heat transfer in Burners and Furnaces:** Open-Flame Burners, Radiant burners, Effects of heat transfer, In-flame treatment, Heat transfer in furnaces, geometry, Furnace types, heat recovery devices, Recuperators, Regenerators, Gas recirculation	**10**	Module will explain conduction, convection, and radiation heat transfer processes occurring in burners and furnaces. Students can evaluate flame heat release, flame temperature profiles, and heat transfer from flame to surrounding surfaces. **Module will also cover b**urner and furnace Design
5	**Combustion Diagnostics:** Overview, Flow Field measurement, Temperature measurement, Species and concentration measurement, Pressure measurement, Soot measurement, droplet and spray measurement	**8**	Module will explain the need for diagnostics to characterize combustion processes, improve efficiency, and reduce emissions. Various Combustion Diagnostic Techniques will be covered.

Course Outcome	• **Understand combustion fundamentals and to analyze combustion reactions and flame types.** • **Evaluate combustion systems in industrial applications.** • Evaluate the design and operation of industrial combustion systems such as furnaces, boilers, engines, and gas turbines. • **Apply diagnostic and measurement techniques.** • **Assess environmental and safety considerations.** • **Design energy-efficient and low-emission combustion systems.**

Learning Resources	5. Charles E. Baukal, Jr., Oxygen enhanced combustion, CRC Press 6. Charles E. Baukal, Jr. Heat Transfer in Industrial Combustion, CRC Press 7. Achintya Mukhopadhyay and Swarnendu Sen, Fundamentals of Combustion Engineering, CRC Press 8. Vasudevan Raghavan, Combustion Technology - Essentials of Flames and Burners, Wiley

Course Code	AM3262N	Course Name	Experimental Stress Analysis	Course Category	OE3	L	T	P
						3	0	0

Pre-requisite Courses	Strength of Materials, Theory of Elasticity desirable	Co-requisite Courses	None	Progressive Courses	Advanced Techniques on Measurement and Testing
Course Offering Department		Aerospace Engineering and Applied Mechanics		Data Book / Codes/Standards	None

Course Objective	The course covers the basic concepts of the analysis and at the end of the course students will be able to 1. Explain the basic aspects of experimental stress analysis that includes exhaustive treatment of the most versatile techniques like photo elasticity and strain gauges 2. Impart a brief introduction to the emerging techniques like digital image correlation. 3. Demonstrate the fundamental aspects of six different experimental techniques 4. Understand the Moiré, Brittle Coatings, Holography, Thermoplastic Stress with practical application

Module	Syllabus	Duration (class-hour)	Module Outcome
1	**Measurements and Extensometers:** Principles of measurement, Accuracy, Sensitivity, Range, Types of Error, Mechanical, Optical, Acoustical and Electrical extensometers and their use, advantage and disadvantage.	10	By the end of this module, students will be able to: • Understand the fundamental principles of measurement including concepts of accuracy, sensitivity, range, and error types.
2	**Strain Gauge – Principles and Strain Measurement:** Principles and operation of electrical strain gauge, Requirement, Type and their uses, Material for strain gauge, Calibration, Bridge sensitivity, Wheatstone bridge and potentiometer circuits for static and dynamic strain measurements, Strain indicator, Rosette Analysis.	8	By the end of this module, students will be able to: • Explain the working principles of electrical strain gauges, including requirements and types (foil, wire, semiconductor). • Identify materials used in strain gauges and understand calibration procedures.
3	**Photoelasticity, Fringe Interpolation Techniques:** Concept of Light, Two dimensional Photo elasticity, Photo elastic effects, Stress optic law, Plane and circular polariscope, Interpretation of fringe pattern, Compensation and separation techniques, Photo elastic material.	8	By the end of this module, students will be able to: • Understand the behavior of light in stress analysis and the concept of two-dimensional photoelasticity.

4	**Non-Destructive Testing-I:** Fundamentals of Non Destructive Testing, Radiography, Ultrasonic Inspection, Ultrasonic C-Scan, Magnetic particles Inspection, Fluorescent penetrant technique, Eddy current testing, Acoustic Emission Technique.	10	By the end of this module, students will be able to: • Understand and apply radiographic and ultrasonic testing methods, including C-scan techniques for material inspection.
5	**Non-Destructive Testing-II:** Fundamentals of brittle coating methods, Analysis of brittle coatings, Industrial application of brittle coating, Introduction to Moiré Techniques, Holography, Thermography.	6	By the end of this module, students will be able to: • Explain brittle coating methods, including coating application, crack pattern interpretation, and industrial uses.

Course Outcome	Upon completing this course, students will be able to: 1. Understand the basic concepts of experimental stress analysis 2. Demonstrate the principles of major types of extensometers 3. Apply the knowledge of Strain gauges in aeronautical domain 4. Understand the principles of Rosette analysis and fringe techniques 5. Understand NDT techniques used in the structural analysis

Learning Resources	**Books:** 1. Daily J. W, Riley W. F (2005), Experimental Stress Analysis, 4th edition, McGraw-Hill, New Delhi. 2. Experimental Stress Analysis by Dally and Riley 3. Experimental Stress Analysis by Srinath and Raghavan 4. Thomas G. Beckwith, Maragoni, Lienhard (2009), Mechanical Measurements, 6th edition, Pearson Education, New Delhi. **Reference Books:** 1. Sadhu Singh (2009), Experimental stress Analysis, 3rd edition, Khanna Publications, New Delhi. 2. Prasad (2011), Non- Destructive Test and Evaluation of Materials, 1st edition, Tata McGraw-Hill, New Delhi.

Course Code	AM3263N	Course Name	Parallel Computation	Course Category	OE3	L	T	P
						3	0	0

Pre-requisite Courses	Basic programming	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department		Aerospace Engineering & Applied Mechanics		Data Book / Codes/Standards	Nil

Course Objective	The objective of Basics of Parallel Computation is to provide students with fundamental concepts and techniques of parallel computing. It aims to develop an understanding of the need for parallel computations and the challenges involved in parallel programming. Students will learn about various parallel architectures and programming paradigms, as well as gain the ability to model and analyse the performance of parallel computations using speedup, efficiency, and scalability metrics. The course also provides hands-on training in parallel programming using the MPI (Message Passing Interface) standard for communication in distributed systems. Additionally, it introduces the basics of GPU programming, covering architectures, accelerators, and frameworks such as CUDA, OpenCL, and OpenACC. Through practical case studies, students will learn to design and implement parallel algorithms for solving scientific and engineering problems, such as matrix computations and partial differential equations.

Module	Syllabus	Duration (class-hrs)	Module Outcomes
1	**Introduction to parallel computation:** Needs for parallel computations. Challenges of parallel programming- Parallel Programming Paradigms – Parallel Architecture - Overview of some parallel systems. Multiprocessors and multi-computers.	6	Students will understand the necessity of parallel computing in modern applications and identify the major challenges associated with parallel programming. They will be able to describe different parallel architectures, programming paradigms, and the structure of multiprocessor and multi-computer systems.
2	**Modeling and analysis of parallel computations:** Efficiency characteristics of parallel computation: speedup, efficiency, scalability - Model analysis: determining the parallel method execution time, estimating the maximum possible parallelization, computational load balancing - The Amdahl's and Gustavson-Barsis's laws - Aggregating the computation model.	8	Students will be able to evaluate the performance of parallel systems by analyzing speedup, efficiency, and scalability. They will develop the skills to model parallel execution time, estimate maximum parallelism, and apply Amdahl’s and Gustafson-

			Barsis's laws to understand the limitations of parallelization.
3	**Parallel programming with MPI and communication:** Overview of the MPI standard. Point-to-point communication operations. Synchronous and asynchronous modes of data transmission. Collective operations. Derived data types. Process management. Logical topologies.	8	Students will gain practical knowledge of the MPI standard and its application in point-to-point and collective communication. They will be able to distinguish between synchronous and asynchronous communication and manage parallel processes using derived data types and logical topologies.
4	**Basics of GPU Programming:** Introduction to GPU Architecture - History, graphics processors, graphics processing units, GPGPUs. Clock speeds, CPU / GPU comparisons, heterogeneity. Accelerators, parallel programming, CUDA / OpenCL / OpenACC.	10	Students will develop a foundational understanding of GPU architectures and learn how to program using CUDA, OpenCL, and OpenACC. They will be able to compare CPUs and GPUs in terms of performance and understand the challenges of heterogeneous computing environments.
5	**Case study on parallel programming:** Algorithm development – selection of communication operations - Case studies: matrix computations, solving partial differential equations – 1D Wave Equation.	10	Students will be able to design and implement parallel algorithms for real-world problems. They will gain hands-on experience in developing parallel solutions for matrix computations and solving partial differential equations such as the 1D wave equation, with a focus on selecting suitable communication and computation strategies.

Course Outcome	● Understand the need for parallel computing and the challenges involved in parallel program design. ● Analyze and model the performance of parallel algorithms using metrics such as speedup, efficiency, and scalability. ● Develop parallel programs using MPI for communication in distributed memory systems. ● Gain foundational knowledge of GPU architectures and implement basic GPU programs using CUDA and OpenCL. ● Design and implement parallel solutions for computational problems such as matrix operations and differential equations.

Learning Resources	1. Grama, Ananth, et al. Introduction to parallel computing. Pearson Education, 2003. 2. Pacheco, Peter. An introduction to parallel programming. Elsevier, 2011. 3. Kirk, David B., and W. Hwu Wen-Mei. Programming massively parallel processors: a hands-on approach. Morgan kaufmann, 2016. 4. Schmidt, Bertil, et al. Parallel programming: concepts and practice. Morgan Kaufmann, 2017. 5. Cai, Yiyu, and Simon See, eds. GPU computing and applications. Singapore: Springer, 2015.

Course Code	AM3264N	Course Name	Micro and Nano-scale Transport Processes	Course Category	OE3	L	T	P
						3	0	0

Pre-requisite Courses	Fluid Dynamics / Fluid Mechanics	Co-requisite Courses	Nil	Progressive Courses	NA
Course Offering Department		Aerospace Engineering and Applied Mechanics		Data Book / Codes/Standards	Nil

Course Objectives	
	• To introduce the students with the emerging and physics-rich field of micro and nano-scale transport. • To cover the basic theoretical concepts and methods used in this subject in a self-contained manner • This interdisciplinary course brings together fluid mechanics, interface science, and electrodynamics with a focused goal of preparing the modern microfluidics researcher to analyze and model continuum fluid mechanical systems encountered when working with micro- and nanofabricated devices

Module	Syllabus	Duration (class-hour)	Module Outcome
I	**Introduction to Microfluidics:** Advantages of miniaturization; Applications of microfluidics; Introduction to Microfabrication techniques, Lab on a CD	4	• Relate to the application areas of microfluidics • Describe modern fabrication methods of micro and nano-scale fluid mechanical systems
II	**Conservation equations and boundary conditions:** Reynolds transport theorem, mass and momentum conservation, First law of thermodynamics, species conservation; No-slip and slip BC	9	• Formulate the governing transport equations from conservation of mass, momentum, energy, and species • Understand the essence of no-slip and slip boundary conditions
III	**Unsteady flows:** Stokes first problem, some examples of oscillating flows, unsteady flows	5	• Obtain exact solutions for Stokes 1st and 2nd problems, unsteady flow induced by shear and oscillating pressure gradient, and discuss their relevance in micro fluidics
IV	**Pressure driven microflows:** Flow through rectangular duct, elliptical duct, annulus, etc.	4	• Obtain analytical solutions for the velocity field, flow rate, and friction factor for non-circular channels

V	**Surface tension driven flows:** Interfacial Equilibrium, Young-Laplace equation; Dimensionless numbers, Lumped system approach; Dynamic contact angle	5	• Formulate appropriate model to relate surface tension with interfacial curvature, pressure difference and contact angle. • Understand the working principle of a capillary-pump, and the Marangoni effect
VI	**Electrokinetics:** Electrostatics, Electric Double Layer, Electroosmotic flow, Joule heating in microchannel, Electrophoresis, Streaming potential, Sedimentation potential	10	• Identify length scales and the velocity scale associated with the electrokinetic effects • Analyse the electroosmotic flow for the special cases of thin-EDL plus low and high zeta-potential. • Formulate the charge conservation (Nernst-Planck) equation • Describe fluidic transport in nanochannels and electroviscosity
VII	**Dispersion**: Hydrodynamic dispersion in a channel, Taylor-Aris dispersion regime; Electrokinetic dispersion; Chromatography; Species separation – Capillary electrophoresis, Free flow zone electrophoresis	5	• Analyse hydrodynamic dispersion of a species in pressure driven flow, • Discuss its relevance in micro-mixing, separation science, and other industrial applications

Course Outcome	On successful completion of this course, students should be able to: • understand the fundamental concepts and methods used in the cross-disciplinary field of microfluidics, which is a prominent branch of Micro-nano Science • use the presented theory as a practical tool, and read and understand research articles on the emerging area of micro and nano-scale transport • develop research interest on microfluidics and lab-on-a-chip systems

Learning Resources	• *Theoretical Microfluidics* by Henrik Bruus, Oxford University Press • *Micro- and Nano-scale Fluid Mechanics - Transport in Microfluidic Devices* by Brian J Kirby, Cambridge University Press. • *Physiochemical Hydrodynamics - An Introduction* by Ronald F Probstein, John Wiley and Sons, Inc.

Course Code	AM3265N	Course Name	Fracture Mechanics	Course Category	OE3	L	T	P
						3	0	0

Pre-requisite Courses	Strength of Materials	Co-requisite Courses	None	Progressive Courses	Course on Structural Design
Course Offering Department		Aerospace Engineering and Applied Mechanics		Data Book / Codes/Standards	None

Course Objective	To introduce the principles of fracture mechanics and equip students with the knowledge to analyze crack initiation, propagation, and failure in materials for safe structural design.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	Overview and Application of Fracture Mechanics Approach to Engineering Design, Effect of Material Properties on Fracture and Failure, Contributions of Inglis, Griffith and Irwin, Classification of LEFM and EPFM, Modes of Loading: Mode-I, Mode-II and Mode-III, Fracture Mechanisms: Brittle Fracture, Ductile Fracture, Fracture Mechanism in Metals and Non-Metals, Void Nucleation and Growth, Ductile Brittle Transition.	06	Understand the fundamental concepts, historical developments, classifications, and practical applications of fracture mechanics in engineering design, including the influence of material properties, loading modes, and fracture mechanisms in metals and non-metals.
II	Linear Elastic Fracture Mechanics (LEFM), Griffith Theory of Energy Balance, Energy Release Rate (G), Instability and R Curve, Stress Intensity Factor, (SIF) K, Relationship Between K and G, Crack-tip Stress and Displacement Field Equations, Westergaard Solution of Stress Field for Mode-I, Mode II, Mode III, SIF for Modeling of Plastic Deformation, Irwin's Model.	14	Understand Linear Elastic Fracture Mechanics (LEFM) principles, including energy-based and stress-based fracture criteria, stress intensity factors, crack-tip fields, and analytical solutions for various loading modes.
III	Elastic Plastic Fracture Mechanics (EPFM), Crack Tip Opening Displacement (CTOD), J Contour Integral, Relationship Between J and CTOD, J Controlled Fracture, Crack Growth Resistance Curves, HRR Field, Dynamic Fracture.	11	Develop an understanding of Elastic-Plastic Fracture Mechanics (EPFM) concepts, including CTOD, J-integral, crack growth resistance, HRR fields, and their applications in

			analyzing stable and dynamic fracture behavior.
IV	Fail-safe and Safe-life approach in Aircraft Design, Crack Initiation and Fatigue Crack Growth, Paris Law, Crack Closure.	04	Understand the principles of fail-safe and safe-life design approaches in aircraft structures, along with the mechanisms of crack initiation, fatigue crack growth, Paris Law, and crack closure effects.
V	Fracture Toughness Testing on Metals.	02	Acquire knowledge of standard fracture toughness testing methods for metals and their significance in evaluating material resistance to crack propagation.
VI	Fracture Mechanics using Finite Element Analysis.	05	Apply finite element analysis techniques to model and evaluate fracture behavior in materials and structures using fracture mechanics principles.

Course Outcome	After competition of the course, students will be able to: • Understand the fundamental concepts of fracture mechanics, including stress intensity factors and energy release rates. • Analyze crack initiation and propagation using linear elastic and elastic-plastic fracture mechanics principles. • Evaluate the fracture toughness of materials and apply failure criteria to structural components. • Assess fatigue crack growth and predict component life under cyclic loading conditions.

Learning Resources	1. T.L. Anderson, Fracture Mechanics - Fundamentals and Applications 2. D. Broek, Elementary Engineering Fracture Mechanics 3. C.T. Sun, Z. –H. Jin, Fracture Mechanics 4. Prashant Kumar, Elements of Fracture Mechanics

Course Code	AM3266N	Course Name	Finite Element Method	Course Category	OE3	L	T	P
						3	0	0

Pre-requisite Courses	Fundamentals of Mechanics, Calculus, Matrix Algebra, Elementary numerical methods, Adequate familiarity with computer	Co-requisite Courses	None	Progressive Courses	Course on Structural Design
Course Offering Department		Aerospace Engineering and Applied Mechanics		Data Book / Codes/Standards	None

Course Objective	Learning versatile and widely used numerical methods to approximately solve practical problems.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	**Overview of Finite Element Method (FEM):** Basic concept; Historical background; Engineering applications; Introduction to Displacement, Force and Mixed Formulations.	03	Students will understand the basic concepts, historical development, and various formulations of the Finite Element Method (FEM) and their applications in engineering.
II	**Basic procedure:** Discretization – Basic element shapes, Node numbering scheme; Interpolation model - Order of polynomial, Generalized and Natural co-ordinates, Convergence requirement, Patch test; Illustrations.	08	Students will learn the FEM discretization process, element shapes, interpolation models, and criteria for convergence using practical illustrations.
III	**Derivation of Characteristic Matrices:** Introduction to Direct approach, Variational approach (Raleigh-Ritz) and Weighted Residual Approach (Collocation, Least Square, Galerkin); Derivation of Finite Element equations using Variational and Weighted Residual Approach; Introduction to Strong and Weak Form formulation; Illustrations.	11	Students will derive finite element equations using direct, variational, and weighted residual approaches, and understand the concepts of strong and weak formulations.

IV	**Assembly and Derivation of System Equations:** Co-ordinate Transformation; Assemblage; Substitution of Boundary Conditions.	06	Students will perform coordinate transformations, assemble global equations, and apply boundary conditions to develop system-level FEM equations.
V	**Numerical Solution of FEM Equations:** Introduction to Band solver and Skyline technique; Applications to Equilibrium and Eigen value problems	10	Students will understand numerical solution techniques for FEM equations with applications to equilibrium and eigenvalue problems.
VI	**Concluding Remarks:** Comparison with other established numerical methods; Introduction to popular FEM packages.	04	Students will compare FEM with other numerical methods and gain an introductory overview of commonly used FEM software packages.

Course Outcome	• Students will understand the fundamental concepts and formulations of the Finite Element Method. • Students will be able to discretize engineering problems and derive element and global system equations. • Students will apply FEM to solve structural, thermal, and other field problems using appropriate numerical techniques. • Students will gain introductory experience with FEM software tools and assess the method's applicability to various engineering scenarios.

Learning Resources	1. The Finite Element Method in Engineering by S. S. Rao 2. An Introduction to The Finite Element Method by J. N. Reddy 3. Fundamentals of Finite Element Analysis by D. V. Hutton 4. Concepts and Applications of Finite Element Analysis by R.D. Cook, D.S. Malkus, M.E. Plesha, and R.J. Witt

Course Code	AM3267N	Course Name	Design Thinking	Course Category	OE3	L	T	P
						3	0	0

Pre-requisite Courses	Nil	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department		Aerospace Engineering and Applied Mechanics		Data Book / Codes/Standards	Nil

Course Objectives	
	• Inculcate the fundamental concepts of design thinking • Provide comprehensive knowledge for effective problem-solving with innovative solutions, prototyping, and testing their viability. • Discover, ideate, and experiment various design-based techniques to gain insight and yield innovative solutions. • Prepare the mindset and discipline of systemic inspiration driven by a desire to identify new sources of ideas, and new models. • Conceive, conceptualize, design and demonstrate innovative ideas using prototypes

Module	Syllabus	Duration (class-hour)	Module Outcome
I	**Introduction & Problem Discovery** Definition, Origin of design thinking, What design thinking is not? What is different about design thinking? Design vs Design thinking, Design Thinking Skills Principles of Design Thinking, The Basis for Design Thinking Design Thinking Process: Types of the thinking process, Common methods to change the human thinking process, Benefits of design thinking. People centered design thinking. Evoking the right problem. An approach to design thinking, Design thinking Process model, Design thinking tools. Applications of design thinking in industries. The Design Thinking Team, Design Thinking – Exercises and case-based discussions.	10	• Acquire deep understanding of the Design Thinking principles, process and tools.
II	**Phases of Design Thinking** Empathize, Define, Ideate, Prototype and Test Listening and Empathizing Techniques – observation – structured open-ended approach, Design Thinking Frameworks, Ideation tools – brainstorming, innovation heuristics, behaviour models, overcoming cognitive fixedness – Exercises and case-based discussions	10	• Demonstrate the critical theories of design, systems thinking, and design methodologies.
III	**Use of Diagrams and Maps in Design Thinking** – Empathy map. Affinity diagram,	10	• Understand the diverse methods employed in design

	mind map, journey map, combining ideas into complex innovation concepts. Story telling – improvisation, scenario planning, development of scenarios, evaluation tools, frog design and prototyping (Prototyping as a mindset, prototype examples, prototyping for products; Fidelity for prototypes, Process of prototyping- Minimum Viable prototype), Prototype using simple things - Wooden model, Clay model, 3D printing Testing - Prototyping for digital products: What's unique for digital products, Preparation; Prototyping for physical products: What's unique for physical products, Preparation; Testing prototypes with users. Exercises and case-based discussions Assess developer and user perspectives for bias – apply frameworks to strengthen communication – sustain a culture of innovation.		thinking and establish a workable design thinking framework to use in their practices. • Iterate and improve the ideas.
IV	**Sustainable product design:** Ergonomics, Semantics, Entrepreneurship/business ideas, Product Data Specification, establishing target specifications, Setting the final specifications. Design projects for teams. Hands-on activities, case studies - General, Engineering, Education, Healthcare and Service applications, and group projects.	12	• Apply Design Thinking framework as a structured Able to solve problems, generate breakthrough ideas and co-create an improved product development experience. • Conceive, organize, lead and implement projects in interdisciplinary domain and address social concerns with innovative approaches
	Total Class	42	

Course Outcome	• Students acquire practical skills and experience in identifying opportunities and fostering innovation. • Acquire deep understanding of the Design Thinking principles, process and tools. • Use AI to create and refine design prototypes and assess their impact on sustainability metrics. • Develop skills such as ethnographers, visual thinkers, strategists and story-tellers. • Apply relevant conceptual frameworks for effective decision-making • Provide a thinking space for innovation of new ventures, value propositions, new products or services.

Learning Resources	• Tim Brown, Change by Design: How Design Thinking Transforms Organizations and Inspires Innovation, HarperCollins Publishers Ltd. • Idris Mootee, Design Thinking for Strategic Innovation,2013, John Wiley & Sons Inc • Victor Papanek: Design for the Real World • Richard Buchanan: Wicked Problems in Design Thinking • Roger Martin, "The Design of Business: Why Design Thinking is the Next Competitive Advantage", Harvard Business Press, 2009.

	• Hasso Plattner, Christoph Meinel and Larry Leifer (eds), "Design Thinking: Understand – Improve– Apply", Springer, 2011 • Jeanne Liedtka, Andrew King, Kevin Bennett, "Book - Solving Problems with Design Thinking - Ten Stories of What Works" (Columbia Business School Publishing), 2013 • Maurício Vianna, Ysmar Vianna, Isabel K. Adler, Brenda Lucena, Beatriz Russo, "Design thinking: Business Innovation" MJV Press, 2011 • Burgelman, Christensen, and Wheelwright, "Strategic Management of Technology and Innovation"5th Edition, McGraw Hill Publications, 2017 • Ulrich & Eppinger, Product Design and Development, 3rd Edition, McGraw Hill, 2004 • Chandramouli Subramanian and Thiyagarajan Paramasivan, "Design Thinking: A Hands-on Approach", Orient Blackswan, 2024.

Course Code	AE3271N	Course Name	Aerodynamics II laboratory	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	Compressible Flow	Co-requisite Courses	Thermodynamics	Progressive Courses	Nil
Course Offering Department		Aerospace Engineering & Applied Mechanics		Data Book / Codes/Standards	Nil

Course Objective	The objective of this course is to provide students with practical exposure to high-speed aerodynamics and compressible flow phenomena through a series of laboratory experiments. Students will gain hands-on experience in conducting experiments related to nozzle flow, shock waves, Mach number measurements, pressure distribution, and aerodynamic drag using facilities such as shock tubes and hypersonic tunnels. Emphasis is placed on understanding theoretical concepts, experimental setup and procedures, data acquisition techniques, and result interpretation with respect to compressible flow theory.

Module	Name of Experiments	Duration (class-hrs)	Module Outcomes
1	Introduction and Visit to lab	6	Brief introduction about lab, safety protocols, and theory/calculations for different experiments.
2	Visual Demonstration of Nozzle Choking	3	To visually demonstrate nozzle choking.
3	Visual Demonstration of Pressure Distribution	6	Visual demonstration and plotting the pressure distribution across a convergent-divergent nozzle.
4	Effect of Inlet Pressure on Mass Flow Rate	6	Determination of the effect of inlet pressure on the mass flow rate, with constant backpressure, and comparison with theoretical predictions.
5	Measurement of freestream Mach number in a hypersonic shock tunnel	3	Students will measure the freestream Mach number inside the test section of a manually operated Hypersonic Shock Tunnel.
6	Measurement of aerodynamic drag on an axisymmetric body in a Hypersonic shock tunnel	3	Students will be measuring the drag force acting on a generic cone-cylinder model, which is subjected to hypersonic flow in a shock tunnel.
7	Measurements in a shock tube	3	Students will do the calibration of a manually operated shock tube.
8	Optical flow visualization	3	Students will learn the optical flow visualization method used for shock wave visualization.
	End-test	3	
	Viva Voce	3	

Course Outcome	• Demonstrate understanding of lab safety protocols and the theoretical background of compressible flow experiments. • Analyze nozzle choking and pressure distribution in convergent-divergent nozzles through visual and quantitative methods. • Evaluate the effect of inlet pressure variations on mass flow rate and validate with theoretical predictions. • Measure freestream Mach number and aerodynamic drag using hypersonic shock tunnels and analyze shock flow properties. • Perform calibration of shock tube setups and apply optical flow visualization techniques to interpret shock wave behavior.

Course Code	AE3272N	Course Name	Aerospace Structures Laboratory	Course Category	PC	L	T	P
						0	0	3

Pre-requisite Courses	Strength of Materials	Co-requisite Courses	None	Progressive Courses	Research Project
Course Offering Department		Aerospace Engineering and Applied Mechanics		Data Book / Codes/Standards	Nil

Course Objective	The objective of the Aerospace Structures Laboratory is to provide students with practical knowledge and experimental skills to analyze structural behavior, including deflection, bending, buckling, and shear in aerospace components, using appropriate instrumentation and data interpretation techniques.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	Introduction of Analog to Digital Converter (HDA200)	03	Students will understand the working principle and applications of the Analog to Digital Converter in structural testing.
II	Deflection of Frames – (i) S – Frame, (ii) Rectangular Portal Frame	06	Students will understand and evaluate the deflection behavior of S-frames and rectangular portal frames through experimental analysis under different loading conditions.
III	Buckling of Thin Struts	03	Students will analyze the buckling behavior of thin struts and determine critical loads through experimental methods.
IV	Shear Centre of Different Thin-walled Sections	06	Students will determine the shear center of various thin-walled sections and understand its significance in preventing twisting under shear loads.
V	Reporting on experiments and necessary corrections	03	Students will learn to document experimental procedures, analyze results, necessary corrections to improve accuracy and reliability.
VI	Bending Stresses in Beams	03	Students will analyze and evaluate bending stresses in beams subjected to various loading conditions.

VII	Plastic Bending of Beams	03	Students will understand and analyze the behavior of beams under plastic bending to determine the ultimate load-carrying capacity.
VIII	Two-dimensional Bending	03	Students will analyze two-dimensional bending in beams and structural members subjected to biaxial loading conditions.
Viva voce		03	

Course Outcome	• Students will gain hands-on experience with structural testing equipment, including the use of analog to digital converters like HDA200. • Students will analyze deflection, bending, and buckling behavior in various aerospace structural elements through experimental methods. • Students will determine critical properties such as shear center and plastic bending capacity of thin-walled and beam structures. • Students will develop skills in experimental reporting, data analysis, and implementing corrections to improve test accuracy and structural understanding.

Learning Resources	• Megson, T.H.G., Aircraft Structures for Engineering Students, Elsevier. • Bruhn, E.F., Analysis and Design of Flight Vehicle Structures, Tri-State Offset. • Aerospace Structures Laboratory Manual

Course Code	AE3273N	Course Name	Aircraft Design and Flight Training	Course Category	PC	L	T	P
						0	0	3

Pre-requisite Courses	Flight mechanics, Aircraft Performance, Engineering Drawing	Co-requisite Courses	NMCT, Aerodynamics, propulsion, Structures	Progressive Courses	Advanced aircraft design, Unmanned Aerial Vehicles
Course Offering Department		Aerospace Engineering and Applied Mechanics		**Data Book / Codes/Standards**	See learning Resources

Course Objective	This course introduces students to the fundamentals of aircraft design and flight testing. It covers reference-based initial sizing, freehand sketching, and weight estimation from mission profiles. Students will analyze and select appropriate airfoils for general aviation and special-purpose aircraft. The course also includes hands-on training with essential flight instruments—pitot-static, gyro, engine, and navigation systems—along with understanding sources of error. Through experiments, students will determine aircraft weight and center of gravity, estimate drag polar during cruise and climb, identify the neutral point, and calibrate control surfaces. The course integrates theory with practical skills to build a foundation in aircraft performance and stability analysis.

Module	Syllabus	Classes	Outcome
1	**Rudimentary design:** Reference aircraft for design, Initial sizing parameters (Using available data, Reports etc), Freehand sketch of the aircraft(Drawing sheet and tools required)	6	Develop an initial aircraft layout using reference designs, sizing parameters, and freehand sketches.
2	**Weight estimation:** Sizing from initial sketch, Mission profiles, calculation of weight fractions based on mission requirements	6	Estimate aircraft weight fractions based on mission profiles and sizing methodology.
3	**Airfoil selection and characteristics:** Airfoil data analysis, Airfoil selection (General Aviation a/c), Airfoil selection (Special design Ex. Sail plane)	6	Analyze airfoil data and select suitable airfoils for various aircraft types.
4	Flight Training: Introduction to Aircraft Instruments: Pitot static tube, Altimeter, Air Speed Indicator, Vertical Speed Indicator, Gyro Instruments, Gyro Horizon, Turn Coordinator, Altitude Heading Indicator, Engine Instruments, Oil Temperature, Oil Pressure, Cylinder Head Temperature, Outside Air Temperature, Manifold Pressure, Engine RPM, Exhaust Gas Temperature, Fuel Tank Capacity	8	Understand the function and interpretation of key flight and engine instruments.
5	Navigational Instruments: VOR, GPS, Sources of error	8	Learn the operation and limitations of VOR, GPS, and navigation systems.

6	Aircraft performance and flight mechanics: Weight, Determination of centre of gravity of Aircraft, Estimation of stick fixed Neutral Point Experiment. Drag Polar Estimation at Cruise, Climb, Calibration of Control Surfaces: Aileron, Elevator	8	Analyze aircraft performance, determine CG, and estimate drag polar and control surface calibration.

Course Outcome	By the end of the course, students will be able to: • Perform basic aircraft design tasks, including sizing, sketching, and weight estimation based on mission profiles. • Analyze and select suitable airfoils for various aircraft types using aerodynamic data. • Identify and explain the function of key flight and engine instruments, as well as navigational systems. • Evaluate common sources of instrumentation error and their impact on flight data. • Conduct and interpret experimental procedures such as CG determination, drag polar estimation, control surface calibration, and neutral point identification. • Apply theoretical knowledge to practical scenarios, demonstrating a foundational understanding of aircraft stability and performance.

Learning Resources	• **Aircraft Design: A Conceptual Approach** – Daniel P. Raymer, AIAA Education Series • **General Aviation Aircraft Design: Applied Methods and Procedures** – Snorri Gudmundsson, Butterworth-Heinemann • **Flight Theory and Aerodynamics** – Charles E. Dole and James E. Lewis (Alternative: *Introduction to Aerodynamics* by Barnes W. McCormick or Carpenter if referring to a specific text)

7th Semester Courses Syllabi

B. Tech in Aerospace Engineering

Course Code	AE4101N	Course Name	Turbulence	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	Fluid Mechanics	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department		Aerospace Engineering and Applied Mechanics		Data Book / Codes/Standards	Nil

Course Objectives	
	• Introduce the basic properties of turbulence: Random fluctuating structures over a large range of length- and time-scales. • Expose the students to theoretical, numerical and experimental techniques used to describe and quantify the effects of turbulence • Introduce students to the turbulence modelling technique

Module	Syllabus	Duration (class-hour)	Module Outcome
I	**General introduction and concepts:** Factors affecting the transition to turbulent flow, classical experiments on the transition to turbulence, energy cascade, role of averaging in turbulent flow, averaging procedures, characteristics of turbulent flow, types of turbulent flow, Kolmogorov microscales of turbulence, other characteristic scales and orders of magnitude	4	Students will be exposed to the different instabilities that leads to turbulence together with the different scales of turbulence.
II	**Fundamental equations for turbulent flow:** Continuity equation for turbulent flow, Reynolds equation of motion, Reynolds stress and correlations, Correlation function, Statistical theory of turbulence, Fourier transform and spectra, Reynolds stress equation, Energy equation in a turbulent flow, Equation for dissipation of energy, Transfer of energy between mean flow and turbulence, Transfer of energy from mean flow to turbulence, Role of pressure.	12	Students will have understanding on the different transport equations of turbulent flow that includes momentum, fluctuating energy, mean energy, Reynolds stress, turbulent dissipation
III	**Wall bounded turbulent flows:** Duct flow, balance of mean forces, near wall shear stress, mean velocity profile, turbulent kinetic energy budget, length scales and mixing length; Turbulent flow in duct; Turbulent flow over flat plate.	6	Students will be able to apply the different transport equations of turbulent flow on different wall bounded turbulent flows

IV	**Free shear turbulent flows:** Description of flow in a turbulent jet, self preservation, analysis of 2-D jet, Integral momentum equation, integral energy equation, entrainment hypothesis, scale relations.	5	Students will be able to apply the different transport equations of turbulent flow on free shear turbulent flows
V	**RANS based Turbulence modelling:** Phenomenological theories of turbulence, Boussinesq's theory, Prandtl's mixing length hypothesis, One equation models, Spalart Allmaras model, k-ε, k-ω, k-ω SST turbulence models	8	Students will be able to apply the different one equation and two equation turbulence closure models in CFD simulations
VI	**Introduction to Large Eddy Simulation (LES):** Convolution integral and the filtering operation, Spectral representation, Filtered energy spectrum, Filtered conservation equations, The Smagorinsky model	7	Students will have understanding on how the large eddy simulation works and the equations that are solved for implementing large eddy simulation

Course Outcome	• Students will become familiar with transport of moment, energy and vorticity in turbulent flows and be familiar with applications of turbulence in industry and environment. • Students will be able to analyze simple shear, wall bounded and boundary layer flows with the use of phenomenological models of turbulence. • Students will become familiar with different turbulence modelling techniques in the context of RANS based approaches and also LES simulations

Learning Resources	1. Turbulence – P.A. Davidson, Oxford University Press 2. Turbulent flows – Stephen B. Pope, Cambridge University Press 3. A first course in turbulence – H. Tennekes and J. L. Lumley, M.I. T press

Course Code	AE4121N	Course Name	Aerospace Structural Dynamics	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	Theory of Vibration, Aerospace Structures	Co-requisite Courses	None	Progressive Courses	Aeroelasticity
Course Offering Department		Aerospace Engineering and Applied Mechanics		Data Book / Codes/Standards	None

Course Objectives	1. Introduce methods for modelling structural dynamics problems using energy principles 2. Study the fundamental concepts of structural vibration relevant to aerospace components modelled as one-dimensional continua 3. Develop analytical skills to determine natural frequencies, mode shapes, and dynamic responses of structural elements under various loading and boundary conditions.

Module	Syllabus	Duration (class-hour)	Module Outcome
1	**Introduction:** Review of Mechanical Vibration**,** Elements of aerospace structures	3	• Students will be able to review the fundamentals of mechanical vibration and aerospace structures
2	**Introduction to Calculus of Variation** Introduction, Functional, The First Variation, Euler-Lagrange Equation, Boundary Conditions	4	• Students will be able to apply the principles of the calculus of variations to derive Euler-Lagrange equations and determine appropriate boundary conditions for solving structural dynamics problems.
3	**Lagrange's Equation and Hamilton's Principle**	5	• Students will be able to formulate and apply Lagrange's equations and Hamilton's principle to model and analyze the dynamic behavior of aerospace structural systems.
4	**Development of a typical Aircraft Vibration Problem**	2	• Students will be able to formulate and solve a typical Aircraft vibration problem using discrete structural elements
5	**Beam Torsional Dynamics** Equation of Motion, General Solution, Boundary Conditions,	7	• Students will be able to derive and solve the equations of motion for beam torsional dynamics, apply boundary conditions, and

	Solution for mode shapes and frequencies.		determine mode shapes and natural frequencies.
6	**Beam Bending Dynamics** Equation of Motion, Boundary Conditions, Solution for mode shapes and frequencies	9	• Students will be able to derive and solve the equations of motion for beam bending dynamics, apply boundary conditions, and determine mode shapes and natural frequencies.
7.	**Approximate Solution Techniques in Structural Dynamics:** Rayleigh-Ritz Method, Galerkin's Method, Finite Element Method	8	• Students will be able to apply approximate solution techniques such as the Rayleigh-Ritz method, Galerkin's method, and the Finite Element Method to analyze dynamic responses of aerospace structures.
8.	**String Dynamics:** Equation of Motion-Standing Wave Solution, Orthogonality of mode Shapes and its implication, Travelling wave solution.	4	• Students will be able to analyze string dynamics by deriving and solving the equations of motion, interpreting standing and travelling wave solutions, and understanding the orthogonality of mode shapes and its implications

Course Outcome	Upon completion of the course, students will be able to: 1. **Formulate and solve dynamic problems** in aerospace structures using principles such as Euler-Lagrange equations, Hamilton's principle, and various analytical and approximate methods including Rayleigh-Ritz, Galerkin's, and Finite Element Methods. 2. **Analyze the vibrational behavior** of structural components such as beams and strings, determine natural frequencies and mode shapes, and apply these concepts to typical aerospace applications including aircraft vibration analysis.

Learning Resources	1. Introduction to Structural Dynamics and Aeroelasticity – D. H. Hodges and G. A. Pierce, Cambridge University Press 2. Elements of Vibration Analysis – L. Meirovitch, McGraw-Hill 3. Energy and Finite Element Methods in Structural Mechanics – I.H. Shames and C.L. Dym, CRC Press 4. Aeroelasticity – R.L. Bisplinghoff, H.Ashley and R.L.Halfman, Dover

Course Code	AE4122N	Course Name	Orbital Mechanics	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	Engg. Mech., Mathematics	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department		Aerospace Engineering & Applied Mechanics		Data Book / Codes/Standards	Nil

Course Objectives	The objective of this course is to provide the basic knowledge on space mechanics, different types of orbits, single universal Kepler's equation for all orbits, different types of coordinate transformations, orbits in 3-D space, different types of coordinate systems used in space mechanics and different types of orbit maneuvers.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	**Two Body Problem:** Introduction; Equation of Motion in an Inertial frame; Equations of Relative Motion; The Orbit Formulas; Energy Law; Different Orbits and Trajectories, Perifocal Frame; The Lagrange Co-efficient	8	Familiar with several fundamental properties of different orbits and restricted three-body problems.
II	**Orbital Position as a Function of Time:** Introduction; Time since Periapsis; Applications to different Orbits and Trajectories	6	Able to apply a single universal Kepler's equation to find the position of a satellite in 2-D plane.
III	**Orbits in Three Dimensions:** Introduction; Geocentric Frames; Orbital Elements and State Vectors, Coordinate Transformation; Application between Geocentric Frames, Effect of Earth's Oblateness; Ground Tracks.	6	Able to explore the means of describing orbits in 3-D space for real missions and orbital maneuvers.
IV	**Preliminary Orbit Determination:** Introduction; Gibbs Method for Orbit Determination; Lambert's Problem; Sidereal Time; Different Topocentric Coordinate Systems; Orbit Determination.	10	Acquainted with some classical ways to determine the orbit of a satellite from earth-bound observations.
V	**Orbital Maneuvers:** Introduction; Impulsive Maneuvers; Hohmann Transfer; Phasing Maneuvers; Hohmann Transfers; Apse Line Rotation; Chase Maneuvers; Phase Change Maneuvers; Non-impulsive Orbital Maneuvers.	12	Students will be familiar with different types of orbital maneuvers (Hohmann, non-Hohmann and non-impulsive maneuver)

Course Outcome	Students will be able to determine the type of orbits, have basic ideas about different types of frames used in space mechanics, how to keep track of a satellite, have knowledge of different types of orbit maneuvers, take part in launch programs of satellites in an orbit and interplanetary mission.

Learning Resources	1. H. D. Curtis, Orbital Mechanics for Engineering Students, B. H., Elsevier 2. J E Prussing, B A Conway, Orbital Mechanics, Oxford University Press

Course Code	AM4161N	Course Name	Fundamentals of Combustion	Course Category	OE4	L	T	P
						3	0	0

Pre-requisite Courses	Thermodynamics, Fluid Mechanics	Co-requisite Courses	Heat transfer	Progressive Courses	Advanced combustion
Course Offering Department		Aerospace Engineering and Applied Mechanics		Data Book / Codes/Standards	

Course Objective	The objective of Fundamental of combustion is to provide students with a thorough Understanding of the Basic Principles of Combustion, and to understand the thermodynamic, fluid dynamic, and chemical principles involved in combustion processes. Topics over Chemical Kinetics and Thermochemistry will also be covered. After completion of course, students can Characterize Different Types of Combustion, and can analyze Transport Phenomena in Combustion Systems. Course will also help to Evaluate Combustion Systems and Applications.

Module	Syllabus	Duration (class-hrs)	Module Outcomes
1	**Introduction:** Introduction to combustion, Application of combustion, Fuel and oxidizer properties, Classification fuel and oxidizers used in propulsion, Various combustion modes, Scope of combustion in propulsion and industries.	4	Module will help to understand the fundamental concepts of combustion, to analyze thermochemical processes, and in-depth application of combustion in various engineering applications.
2	**Combustion kinetics:** Fundamentals of combustion kinetics, Elementary reactions, Chain reactions, Multistep reactions, simplification of reaction mechanism, Global kinetics, rate equations, equilibrium constant, Gibb's free energy	8	Module will help in understanding fundamental principles of chemical kinetics, to analyse combustion reaction mechanisms, to apply Arrhenius law and rate constants, and to evaluate the role of kinetics in pollutant formation.
3	**Flames:** ***Laminar and turbulent Premixed flames*** (Physical description, Rankine-Hugonoit relations, Flame propagation and flame speed, Determination of flame speed, Factors effecting flame speed, Flame quenching and ignition, Limit phenomena – flammability limits, ignition, and flame stabilization) ***Laminar and turbulent diffusion flames*** *(*Physical description, analysis of diffusion-controlled systems, Shvab-Zeldovich Formulation, Analysis of typical laminar non-premixed flames, Partially premixed flames, Effect of jet velocity on jet flames) **Other topics:** Droplet and spray combustion.	14	Module will help students to understand the physical and chemical structure of flames, to analyze flame propagation and flame speed, and to examine flame stabilization and quenching mechanisms. Students will be able to distinguish between laminar and turbulent flame behavior, interpret experimental observations of flames, and evaluate practical applications involving flames.

4	**Metal Combustion:** Importance of metal combustion in propulsion, physical description of metal combustion, Combustion mechanisms of Aluminum and Boron in various flow conditions, other metal combustion	6	Module will help students to explain the fundamentals of metal combustion, to analyze the thermodynamics and kinetics of metal reactions, to evaluate combustion behavior of common metallic fuels, to understand surface and vapor phase combustion mechanisms. Students will be able to apply models to predict metal particle combustion under various conditions.
5	**Combustion applications in Propulsion:** Combustion in aircraft engines, flame holders, solid propellant combustion models, Principal ideas of combustion in liquid propellant rockets, Combustion in boundary layers and hybrid rockets.	10	Module will help students to **assess** applications of combustion in propulsion and energetics. Various combustion models will be covered in the module which will help students to analyse combustion of any given materials and energy applications.

Course Outcome	• Understand Basic Combustion Principles and to apply Thermodynamics and Chemical Kinetics. • Model Premixed and Diffusion Flames. • Evaluate Combustion in Practical Systems through Numerical and Analytical Tools. • Understand Safety and Environmental Impacts. • To model combustion of any materials mathematically

Learning Resources	9. K K Kuo, Principles of Combustion, John Wiley and Sons 10. J.G. Quintiere, Fundamentals of fire phenoeana, John Wiley and Sons 11. SR Turns, An introduction to combustion, McGraw Hill 12. Achintya Mukhopadhyay and Swarnendu Sen, Fundamentals of Combustion Engineering, CRC Press

Course Code	AM4162N	Course Name	Convective heat and mass transfer	Course Category	OE4	L	T	P
						3	0	0

Pre-requisite Courses	Fluid Mechanics / Fluid Dynamics	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department		Aerospace Engineering and Applied Mechanics		Data Book / Codes/Standards	Nil

Course Objectives	
	• To cover the fundamentals of Convection heat transfer with emphasis on the analytical (mathematical) treatment of laminar flows in both internal and external flow configurations • Specific attention is given to the theory of thermal boundary layer, fully developed and developing internal flows, exact and approximate methods of the solution for steady, incompressible flows • To introduce basics of turbulent convection and natural convection

Module	Syllabus	Duration (class-hour)	Module Outcome
I	**Introduction:** Different modes of heat transfer, Fourier's law of heat conduction, Newton's law of cooling	2	• Understand various modes of heat transfer
II	**Conservation principles:** Mass and momentum conservation equations, Energy equation, Dimensionless forms of equation of motion and energy equation, dimensionless parameters in heat transfer	6	• Formulate the governing transport equations, • Identify important dimensionless numbers and understand their physical significance
III	**Forced convection in laminar external boundary layer:** Boundary layer equations for momentum and energy; Reynolds analogy; scale analysis; similarity solutions for thermal boundary layer; Integral method; heat transfer correlations	8	• Formulate integral boundary layer equations for momentum and energy, and evaluate Nusselt No. for the limiting cases of high and low Prandtl numbers (Pr) • Obtain exact solutions for three cases (Pr =1, Pr << 1, and Pr >>1) • Apply superposition principle for complex problems with arbitrary wall temperature
IV	**Forced convection in laminar internal flow:** Bulk mean temperature, Thermally fully developed flow through circular ducts and parallel plate channels, uniform temperature and uniform heat flux boundary conditions; Thermally developing flow; Heat transfer with viscous dissipation	10	• Formulate energy balance for internal flow, • Obtain analytical solutions (Nusselt No.) for parallel-plate channel and circular tube with constant wall temperature and uniform wall heat flux BC, • Analyse a channel flow problem with viscous dissipation

V	**Forced convection in turbulent boundary layer and turbulent internal flow:** Reynolds averaging method, Time-averaged energy equation for turbulent boundary layer, thermal eddy diffusivity; Convection correlations for internal and external flows	6	• Understand the effects of turbulent flow on heat convection, • Calculate convective heat transfer coefficients for practical problems
VI	**Free convection:** Laminar natural convection along vertical plates, enclosures, exact solutions for constant wall temperature and constant wall heat flux; Integral solutions; Different regimes of free convection	6	• Identify dimensionless numbers relevant for natural convection and understand their physical significance • Perform boundary layer calculations for free convection
VII	**Mass transfer**: the concentration boundary layer, convection coefficients for mass transfer; Film condensation on a vertical flat plate	4	• Analyse film condensation along a vertical plate

Course Outcome	On successful completion of this course, students should be able to: • Develop an understanding of the fundamentals of convection heat transfer – both physics as well as appropriate mathematical models. • Solve various problems on thermal convection involving vast engineering applications. • Improve their analytical ability and overall knowledge of transport phenomena.

Learning Resources	• Convective Heat and Mass Transfer by W M Kays and M E Crawford, McGraw-Hill • Fundamentals of Heat and Mass Transfer by Incropera, Dewitt, Bergman & Lavine, John Wiley & Sons, Inc. • Convection Heat Transfer by Adrian Bejan, Wiley-India.

Course Code	AM4163N	Course Name	Industrial Hydraulics and Pneumatics	Course Category	OE4	L	T	P
						3	0	0

Pre-requisite Courses	Nil	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department		Aerospace Engineering and Applied Mechanics		Data Book / Codes/Standards	Nil

Course Objectives	Oil hydraulics and air pneumatics as fluid power play an important role in many sectors of the industry. It is used in machine tools, mining machinery, off-road vehicles, material handling / testing systems and aviation etc. • Introduce hydraulic and pneumatic components, circuits, and systems. • Provide theoretical knowledge in designing, modeling, analyzing and implementing control systems for real and physical systems;

Module	Syllabus	Duration (class-hour)	Module Outcome
	HYDRAULICS		
1	**Introduction to oil hydraulics and pneumatics:** Advantages and limitations. Properties of fluids, Fluids for hydraulic systems, governing laws. distribution of fluid power, ISO symbols, energy losses in hydraulic systems. Applications, Basic types and constructions of Hydraulic pumps (Gear Pumps, Vane Pumps, Piston Pumps) and motors. Pump and motor analysis. Performance curves and parameters, Hydraulic actuators (cylinders and motors), Accumulator-Applications.	7	• Fluid mechanics and governing laws • Pump, motors and actuators
2	**Control Valves:** Types and constructional details, lever systems, control elements – direction, pressure and flow control valves. Check valves, Valve configurations, General valve analysis, valve lap, flow forces and lateral forces on spool valves. Flapper valve Analysis and Design.	7	• Fundamentals and specific cases of control valves such as direction, pressure and flow control.
3	**Drawing, design and analysis of typical hydraulic circuits:** Regenerative circuits, high low circuits, Synchronization circuits, and accumulator sizing. Intensifier circuits Meter-in, Meter-out and Bleed-off circuits; Fail Safe and Counter balancing circuits, accessories used in fluid power system.	6	• Hydraulic circuits design and control.
	Fluid Power in Machine Tools and Other Equipment: Introduction, Hydraulic Clamping Circuits in machine Tools, Speed Control in One Direction (DCV and FCV Combination), Meter-in Feed Circuit (DCV and FCV Combination), Meter-out Circuit DCV and FCV Combination), Speed Control in Both Directions (DCV and FCV Combination)—Tank	4	• Industrial application of hydraulic power

	Line Feed Control, Hydraulic circuit for Plastic Injection Molding Machine, Hydraulic Press Application.		
PNEUMATICS			
4	**Components of pneumatic systems:** Air-Compression System, Types, Compressor specifications, Direction, flow and pressure control valves in pneumatic systems. Development of single and multiple actuator circuits. Valves for logic functions; Time delay valve; Exhaust and supply air throttling; Fluid Power Circuit Design (Pneumatics), Control Air vs Signal Air, Building a Pneumatic Circuit, Speed control Circuits, Position Sensing in Pneumatic Cylinders, Pressure Sensing in Pneumatic Circuits. Pilot-operated solenoid valve, Electrical limit switches and proximity switches, Relays, Solenoids. Examples of typical circuits using displacement – time and travel-step diagrams. Will-dependent control, Travel-dependent control and Time-dependent control, combined control, Program control, Electro-pneumatic control and air-hydraulic control. Applications in assembly, feeding, metalworking, materials handling and plastics working.	9	• Pneumatic systems-Concepts and Components. • Design of Pneumatic Circuits. • Electro-pneumatics. • Pneumatic circuits design and control.
APPLICATIONS OF HYDRAULICS AND PNEUMATICS			
5	**Servo and Proportional Systems:** Proportional control valves and servo valves. Nonlinearities in control systems (backlash, hysteresis, dead band and friction nonlinearities), Closed-loop control, Hydromechanical Servo System, Electrohydraulic Servo Valve System, Conventional Valves vs Proportional Valves, Proportional Valves in Hydraulic Circuits, Characteristics of proportional Valves and Servo Valves.	5	• Proportional and servo valve technology.
6	**PLC applications in Fluid Power:** Introduction, Logic in Ladder Diagrams and Mnemonics.	2	• Automation in hydraulic and pneumatic system.
7	**Failure and Troubleshooting in Fluid Power Systems:** Filtration systems and maintenance of system. Troubleshooting - Oil Hydraulics and Pneumatics	2	• Industrial maintenance and trouble shooting

Course Outcome	After successfully completing this course, students will: • Understand hazards of hydraulic and pneumatic circuits and be able to work safely. • Understand the concepts of fluid statics and dynamics as applied to commercial and industrial control. • Recognize standard schematic symbols for common fluid power components. • Understand and troubleshoot basic fluid power, electro-hydraulic, and electro-pneumatic circuits using schematic diagrams. • Understand the operation, application, and maintenance of common fluid power components such as pumps, compressors, valves, cylinders, motors, rotary actuators, accumulators, pipe, hose, and fittings etc.

Learning Resources	**Books**: 1. Introduction to Hydraulics and Pneumatics by Ilango and Soundararajan (PHI) 2. Hydraulics and Pneumatics by Jagadeesha T (I.K. international) 3. Hydraulic and Pneumatic Controls by R Srinivasan 4. Pneumatic Systems: Principles and Maintenance - S Majumdar 5. Fluid Power Control, Jagadeesha T, Wiley India Limited.

Course Code	AM4164N	Course Name	Rotorcraft Dynamics	Course Category	OE4	L	T	P
						3	0	0

Pre-requisite Courses	Aerodynamics, Linear Algebra, Differential Equation	Co-requisite Courses	Rotorcraft dynamics	Progressive Courses	Advanced aircraft design, Unmanned Aerial Vehicles
Course Offering Department		Aerospace Engineering and Applied Mechanics		Data Book / Codes/Standards	See learning Resources

Course Objective	To provide a foundational understanding of helicopter, VTOL and multirotor aerodynamics, covering historical development, momentum and blade element theories, performance estimation, rotor dynamics, trim analysis, and aerodynamic interactions in multirotor systems.

Module No.	Syllabus	Duration (class-hour)	Module outcomes
1	Historical development; helicopter and VTOL configurations: Tandem, Coaxial, Intermeshing, Conventional tail, NOTAR, Tilt rotor, Quad plane, eVTOL.	4	Understand the evolution and configurations of rotary-wing and VTOL aircraft.
2	Momentum theory: hovering and axial vertical flight -Aerodynamics of Climb and descend, forward flight, Autorotation	5	Analyze basic helicopter performance using momentum theory in hover and forward flight.
3	Blade Element Momentum Theory: Propeller geometry, Hover and forward flight, Effect of disc loading, figure of merit, Cp, Cq, CT, Efficiency, Inflow ratio, Propeller tip vortex, Windmilling propeller, Effect of no. of blades, rotor solidity, disc loading. Aerodynamics of Ducted Fan.	6	Estimate aerodynamic forces on rotor blades in various flight regimes.
4	Helicopter Performance estimation: power required for hover, climb, level flight, Dissymmetry of lift in forward flight, maximum level speed, speed for best endurance and range, Propeller Aerodynamics in Hover vs. Forward Flight	6	Estimate helicopter performance metrics and power requirements across different flight modes.
5	Helicopter Rotor blade and hub idealization, Blade flap response, Example problem of helicopter trim in forward flight, delta3 coupling.	4	Idealize rotor blade and hub systems of helicopter. Model the flap dynamics. coupled trim analysis to determine equilibrium conditions

6	Aerodynamic Principles of Multirotors: Flight dynamic model of a quadrotor, Effect of Rotor Spacing and Configuration on Flow Interaction, Control schema, Power estimation, aerodynamics in Forward flight, induced Flow, propwash, Downwash in Multirotor Systems	4	Examine dynamic coupling effects between rotor blade motions for advanced flight analysis.

Course Outcome	By the end of the course, students will be able to: • Explain the evolution and configurations of helicopters and VTOL systems. • Apply momentum and blade element theories to analyze rotor performance. • Estimate power requirements for various flight conditions. • Model rotor dynamics including flap response and trim analysis. Analyze aerodynamic interactions in multirotor systems, including lift generation and rotor flow effects

Learning Resources	1. Principles of Helicopter Aerodynamics- Gordon J. Leishman, 2nd Edition, Cam bridge Aerospace Series, 2006. 2. Rotorcraft Aeromechanics- Wayne Johnson, Cambridge University Press, Apr 2013. 3. Fundamentals of Helicopter Dynamics, C. Venkatesan, CRC Press, 2014. 4. Helicopter Flight Dynamics- Gareth D. Pad eld, 2nd Edition, Wiley-Blackwell, May 2008. 5. Basic Helicopter Aerodynamics, J. Seddon, 3rd Edition, Wiley, 2011. 6. Helicopter Performance, Stability and Control, R. W. Prouty, Krieger Publishing Company, Florida, 1986

Course Code	AE4171N	Course Name	Flow Visualization Laboratory	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	• Fluid Mechanics • Compressible Flows • Instrumentation and Measurement Techniques	Co-requisite Courses	• Wind Tunnel Techniques • Experimental Methods in Aerospace Engineering	Progressive Courses	• Hypersonic Flow and Propulsion • Advanced Flow Diagnostics and Instrumentation
Course Offering Department		Aerospace Engineering and Applied Mechanics		**Data Book / Codes/Standards**	See learning Resources

Course Objective	The primary objectives of this laboratory course are to: 1. Expose students to classical and modern flow visualization techniques for internal and external flows. 2. Provide hands-on experience with optical diagnostics like Schlieren, shadowgraph, and oil flow methods. 3. Integrate quantitative measurements using Pitot probes to analyze subsonic and supersonic jet characteristics. 4. Enable understanding of supersonic wind tunnel design and calibration for visual experiments. 5. Encourage independent thinking through open-ended experimental design and project execution.

Module	Syllabus	Duration (class-hour)	Module outcomes
1	**Introduction & Safety Training:** Lab orientation, safety protocols, introduction to visualization tools	03	Understand lab protocols, safety procedures, and basic flow visualization tools.
2	**Design and Understanding of Supersonic Wind Tunnel**	03	Learn the fundamental components and working principles of a supersonic wind tunnel.
3	**Calibration of Supersonic Wind Tunnel**	03	Gain hands-on experience in calibrating wind tunnel parameters using standard techniques.
4	**Visualization of Free Jet:** Schlieren and Shadowgraph optical visualization techniques	06	Apply Schlieren and shadowgraph methods to observe flow features in free jets.
5	**Visualization of Wall-Bounded Jet:** Jet over a flat surface at various angles (Schlieren and Oil flow visualization techniques)	06	Visualize jet interaction with solid surfaces using Schlieren and oil flow techniques.
6	**Pitot Measurement: Subsonic Jet** Identifying various flow regions of low-subsonic jet	03	Measure and analyze pressure distribution in low-subsonic jet flows using Pitot probes.

7	**Centerline Pressure Decay** Pressure decay and shock-cell structure along the jet centerline	06	Evaluate shock-cell structures and pressure decay in supersonic jets using quantitative measurements.
8	**Project Experiment / Viva** Group project based on a complex setup	06	Develop and demonstrate the ability to independently plan, execute, and present a flow visualization experiment.
9	Make-up classes	06	Opportunity to repeat missed experiments or reinforce conceptual understanding.

Course Outcome	By the end of the course, students will be able to: 14. Identify and apply appropriate flow visualization techniques such as Schlieren, shadowgraph, and oil flow methods across different flow regimes. 15. Operate and calibrate a supersonic wind tunnel while understanding its design, working principles, and associated safety protocols. 16. Interpret complex flow features including boundary layers, jet spreading, shock cells, and stagnation regions using qualitative and quantitative data. 17. Perform pressure measurements using Pitot probes in subsonic and supersonic jets, and design open-ended experimental studies with clear technical reporting and presentation.

Learning Resources	**Textbooks:** • Goldstein, R.J., *Fluid Mechanics Measurements*, Taylor & Francis. • Settles, G.S., *Schlieren and Shadowgraph Techniques*, Springer. • Rathakrishnan, E., *Instrumentation, Measurements, and Experiments in Fluids*, CRC Press.