MK UNIVERSITY

PATAN, GUJARAT

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MK University, Patan
Faculty of Engineering Technology,
Department of Aeronautical Engineering (AE)

B. TECH (Aeronautical Engineering) SEM-I

SR NO.	COURSE TYPE	COURSE CODE	COURSE NAME	LECTURE (HRS.)/ WEEK	PRACTICAL (HRS.)/ WEEK	CREDITS	EXAMINATION INTERNAL	EXAMINATION EXTERNAL	TOTAL MARKS
1	MAJOR	BTAE101	ENGINEERING MATHEMATICS-I	4	0	4	40	60	100
2	MAJOR	BTAE102	ENGINEERING PHYSICS	4	2	6	90	60	150
3	MAJOR	BTAE103	INTRODUCTION TO AERONAUTICS	4	0	4	40	60	100
4	MINOR	BTAE104	ENGINEERING GRAPHICS & CAD	4	2	6	90	60	150
5	VAC	BTAE105	COMMUNICATION SKILLS-I	2	0	2	0	50	50
TOTAL				18	4	22	260	290	550

B. TECH (Aeronautical Engineering) SEM-II

SR NO.	COURSE TYPE	COURSE CODE	COURSE NAME	LECTURE (HRS.)/ WEEK	PRACTICAL (HRS.)/WEEK	CREDITS	EXAMINATION INTERNAL	EXAMINATION EXTERNAL	TOTAL MARKS
1	MAJOR	BTAE201	ENGINEERING MATHEMATICS-II	4	0	4	40	60	100
2	MAJOR	BTAE202	ENGINEERING MECHANICS	4	0	4	40	60	100
3	MAJOR	BTAE203	COMPUTER PROGRAMMING	4	2	6	90	60	150
4	MINOR	BTAE204	MATERIALS SCIENCE FOR AEROSPACE	4	0	4	40	60	100
5	VAC	BTAE205	WORKSHOP PRACTICE	0	4	4	0	100	100
TOTAL				16	6	22	210	340	550

B. TECH (Aeronautical Engineering) SEM-III

SR NO.	COURSE TYPE	COURSE CODE	COURSE NAME	LECTURE (HRS.)/ WEEK	PRACTICAL (HRS.)/ WEEK	CREDITS	EXAMINATION INTERNAL	EXAMINATION EXTERNAL	TOTAL MARKS
1	MAJOR	BTAE301	FLUID MECHANICS	4	0	4	40	60	100
2	MAJOR	BTAE302	THERMODYNAMIS	4	0	4	40	60	100
3	MAJOR	BTAE303	AIRCRAFT STRUCTURES-I	4	2	6	90	60	150
4	MINOR	BTAE304	AEROSPACE MATERIALS	4	0	4	40	60	100
5	SEC	BTAE305	INTRODUCTION TO AI/ML	4	2	6	90	60	150
TOTAL				20	4	24	300	300	600

B. TECH (Aeronautical Engineering) SEM-IV

SR NO.	COURSE TYPE	COURSE CODE	COURSE NAME	LECTURE (HRS.)/ WEEK	PRACTICAL (HRS.)/ WEEK	CREDITS	EXAMINATION INTERNAL	EXAMINATION EXTERNAL	TOTAL MARKS
1	MAJOR	BTAE401	AERODYNAMICS-I	4	2	6	90	60	150
2	MAJOR	BTAE402	STRENGTH OF MATERIALS	4	2	6	90	60	150
3	MAJOR	BTAE403	AIRCRAFT PROPULSION-I	4	2	6	90	60	150
4	MINOR	BTAE404	FLIGHT MECHANICS	2	0	2	00	50	50
5	SEC	BTAE405	INDIAN KNOWLEDGE SYSTEM	2	0	2	00	50	50
TOTAL				16	6	22	270	280	550

B. TECH (Aeronautical Engineering) SEM-V

SR NO.	COURSE TYPE	COURSE CODE	COURSE NAME	LECTURE (HRS.)/ WEEK	PRACTICAL (HRS.)/WEEK	CREDITS	EXAMINATION		TOTAL MARKS
							INTERNAL	EXTERNAL	
1	MAJOR	BTAE501	AERODYNAMICS-II	4	2	6	90	60	150
2	MAJOR	BTAE502	AIRCRAFT STRUCTURES-II	4	2	6	90	60	150
3	MAJOR	BTAE503	AIRCRAFT PROPULSION-II	4	2	6	90	60	150
4	MINOR	BTAE504	AVIONICS SYSTEMS	2	0	2	00	50	50
5	VAC	BTAE505	WIND TUNNEL TESTING	2	0	2	00	50	50
6	SEC	BTAE506	INDUSTRIAL TRAINING-I	0	2	2	00	50	50
TOTAL				16	8	24	270	330	600

B. TECH (Aeronautical Engineering) SEM-VI

SR NO.	COURSE TYPE	COURSE CODE	COURSE NAME	LECTURE (HRS.)/ WEEK	PRACTICAL (HRS.)/WEEK	CREDITS	EXAMINATION		TOTAL MARKS
							INTERNAL	EXTERNAL	
1	MAJOR	BTAE601	FLIGHT DYNAMICS & CONTROL	4	2	6	90	60	150
2	MAJOR	BTAE602	AEROSPACE VEHICLE DESIGN	4	2	6	90	60	150
3	MAJOR	BTAE603	HEAT TRANSFER	4	2	6	90	60	150
4	MINOR	BTAE604	UAV SYSTEMS	2	0	2	00	50	50
5	VAC	BTAE605	FLIGHT SIMULATION LAB	0	4	4	50	50	100
6	SEC	BTAE606	INDUSTRIAL TRAINING-II	0	2	2	00	50	50
TOTAL				14	12	26	320	330	650

B. TECH (Aeronautical Engineering) SEM-VII

SR NO.	COURSE TYPE	COURSE CODE	COURSE NAME	LECTURE (HRS.)/ WEEK	PRACTICAL (HRS.)/ WEEK	CREDITS	EXAMINATION INTERNAL	EXAMINATION EXTERNAL	TOTAL MARKS
1	MAJOR	BTAE701	COMPUTATIONAL FLUID DYNAMICS	4	2	6	90	60	150
2	MAJOR	BTAE702	AIRCRAFT SYSTEMS ENGINEERING	4	2	6	90	60	150
3	MAJOR	BTAE703	SPACE TECHNOLOGY	4	2	6	90	60	150
4	MINOR	BTAE704	ADDITIVE MANUFACTURING LAB	0	2	2	00	50	50
5	VAC	BTAE705	Project Phase-I	0	4	4	50	50	100
TOTAL				12	12	24	320	280	600

B. TECH (Aeronautical Engineering) SEM-VIII

SR NO.	COURSE TYPE	COURSECODE	COURSE NAME	LECTURE (HRS.)/ WEEK	PRACTICAL (HRS.)/ WEEK	CREDITS	EXAMINATION INTERN AL	EXAMINATION EXTERNAL	TOTAL MARKS
1	MAJOR	BTAE801	AIROSPACE MANUFACTURING	4	2	6	90	60	150
2	MAJOR	BTAE802	AEROSPACE REGULATIONS & SAFETY	4	0	4	40	60	100
3	MINOR	BTAE803	INTRODUCTION TO ROBOTICS	4	2	6	90	60	150
4	SEC	BTAE804	Project Phase-II	0	8	8	100	100	200
TOTAL				12	12	24	320	280	600

SUBJECT CODE: BTAE101

SUBJECT NAME: ENGINEERING MATHEMATICS-I

Course Objective:

- The concept of rank of a matrix which is used to know the consistency of system of linear equations and also to find the eigen vectors of a given matrix.
- Finding maxima and minima of functions of several variables.
- Applications of first order ordinary differential equations. (Newton's law of cooling, Natural growth and decay)
- How to solve first order linear, nonlinear partial differential equations and also method of separation of variables technique to solve typical second order partial differential equations.
- Solving differential equations using Laplace Transforms.

Course Outcomes: At the end of the course students shall be able to

CO1	The concept of rank of a matrix which is used to know the consistency of system of linear equations and also to find the eigen vectors of a given matrix
CO2	Finding maxima and minima of functions of several variables
CO3	Applications of first order ordinary differential equations
CO4	How to solve first order linear, nonlinear partial differential equations and also method of separation of variables technique to solve typical second order partial differential equations

Unit	Content	Credit	Weightage
I	Matrices Introduction, types of matrices-symmetric, skew-symmetric, Hermitian, skew-Hermitian, orthogonal, unitary matrices. Rank of a matrix - echelon form, normal form, consistency of system of linear equations (Homogeneous and Non-Homogeneous). Eigen values and Eigen vectors and their properties (without proof), Cayley-Hamilton theorem (without proof), Diagonalization.	1	25%
II	Functions of Several Variables Limit continuity, partial derivatives and total derivative. Jacobian-Functional dependence and independence. Maxima and minima and saddle points, method of Lagrange multipliers, Taylor's theorem for two variables.	1	25%
III	Ordinary Differential Equations First order ordinary differential equations: Exact, equations reducible to exact form. Applications of first order differential equations - Newton's law of cooling, law of natural growth and decay. Linear differential equations of second and higher order with constant coefficients: Non-homogeneous term of the type f(x) = eax, sinax, cosax, xn , eax V and xn V. Method of variation of parameters.	1	25%

IV	Partial Differential Equations Introduction, formation of partial differential equation by elimination of arbitrary constants and arbitrary functions, solutions of first order Lagrange's linear equation and non-linear equations, Charpit's method, Method of separation of variables for second order equations and applications of PDE to one dimensional (Heat equation).	1	25%

TEXT BOOKS:

1. Higher Engineering Mathematics by B V Ramana ., Tata McGraw Hill.
2. Higher Engineering Mathematics by B.S. Grewal, Khanna Publishers.
3. Advanced Engineering Mathematics by Kreyszig, John Wiley & Sons.

REFERENCE BOOKS:

i)Advanced Engineering Mathematics by R.K Jain & S R K Iyenger, Narosa Publishers.
ii)Advanced Engineering Mathematics by Michael Green Berg, Pearson Publishers.
iii)Engineering Mathematics by N.P Bali and Manish Goyal.

SUBJECT CODE: BTAE102

SUBJECT NAME: ENGINEERING PHYSICS

Course Objectives:

- To provide a foundation in fundamental physics concepts relevant to electrical engineering applications.
- To understand electromagnetic theory, semiconductor physics, and materials science in electrical contexts.
- To apply physical principles to analyze and design electrical devices, circuits, and systems.
- To develop problem-solving skills through theoretical analysis and practical experimentation.

Course Outcomes: At the end of the course students shall be able to

CO1	Apply concepts of electromagnetism to analyze electric and magnetic fields in engineering systems.
CO2	Explain semiconductor physics and its relevance to electronic and electrical devices.
C03	Analyze wave optics, laser physics, and photonic devices used in optical communication and sensing.
C04	Characterize materials (dielectric, magnetic, superconducting) and their applications in electrical engineering.

Unit	Content	Credit	Weightage
I	**Electromagnetic Theory & Applications** • **Vector Analysis:** Gradient, divergence, curl, Gauss's and Stokes' theorems. • **Electrostatics:** Coulomb's law, electric field, Gauss's law, electric potential, capacitance. • **Magnetostatics:** Biot-Savart law, Ampere's law, magnetic materials, inductance. • **Maxwell's Equations:** Integral and differential forms, displacement current, electromagnetic waves. • **Applications:** Transmission lines, waveguides,	1	25%

	antennas (basic concepts).		
II	**Semiconductor Physics & Devices** • **Band Theory of Solids:** Conductors, semiconductors, insulators, Fermi level. • **Intrinsic & Extrinsic Semiconductors:** Carrier concentration, mobility, conductivity. • **PN Junction Diode:** Formation, depletion region, forward and reverse bias, diode equation. • **Special Semiconductor Devices:** Zener diode, LED, photodiode, solar cells. • **Transistor Basics:** BJT and MOSFET structure (introduction). **Module 3: Wave Optics & Laser Physics**	1	25%
III	**Wave Optics & Laser Physics** • **Interference:** Young's double slit, thin films, Newton's rings. • **Diffraction:** Single slit, diffraction grating, resolving power. • **Polarization:** Types, Malus's law, Brewster's law. • **Lasers:** Stimulated emission, population inversion, He-Ne and semiconductor lasers. • **Applications:** Fiber optics, holography, optical sensors.	1	25%
IV	**Materials Science for Electrical Engineering** • **Dielectric Materials:** Polarization mechanisms, dielectric constant, losses, applications in capacitors. • **Magnetic Materials:** Dia-, para-, ferro-, ferri-magnetism, hysteresis, applications in transformers and motors. • **Superconductivity:** Meissner effect, Type I and II superconductors, applications in power transmission and MRI. • **Nano materials:** Quantum dots, carbon nanotubes, applications in sensors and electronics. • **Thermal Properties:** Thermal conductivity, expansion, thermoelectric effects.	1	25%

Textbooks:

- *Engineering Physics* – R. K. Gaur & S. L. Gupta (Dhanpat Rai Publications)
- *A Textbook of Engineering Physics* – M. N. Avadhanulu & P. G. Kshirsagar (S. Chand)
- *Fundamentals of Physics* – Halliday, Resnick & Walker (Extended for Engineers)

Reference books:

- *Electromagnetic Waves and Radiating Systems* – E. C. Jordan & K. G. Balmain
- *Principles of Electronics* – V. K. Mehta (for semiconductor sections)
- *Introduction to Solid State Physics* – Charles Kittel
- *Optics* – Ajoy Ghatak
- *Materials Science and Engineering* – William D. Callister

Online Platforms:

- NPTEL:
  - *Engineering Physics* – IIT Madras

- *Electromagnetic Theory* – IIT Bombay
- *Semiconductor Physics* – IIT Kanpur

- Coursera:
  - *Introduction to Electromagnetism* – Rice University
  - *Optics and Photonics* – MIT

PRACTICAL LIST:

Module 1: Electromagnetism & Measurements

- Magnetic Field Measurement using Helmholtz coil and Gauss meter.
- Verification of Biot-Savart Law for a current-carrying conductor.
- Measurement of Dielectric Constant of different materials.
- Study of Earth's Magnetic Field using tangent galvanometer.

Module 2: Semiconductor Devices & Characteristics

- V-I Characteristics of PN Junction Diode and Zener diode.
- Determination of Energy Band Gap of a semiconductor using four-probe method.
- Characteristics of Photodiode/LED and study of photoelectric effect.
- Solar Cell Characteristics: I-V curve, efficiency calculation.

Module 3: Optics & Lasers

- Determination of Wavelength using diffraction grating.
- Newton's Rings Experiment for wavelength determination.
- Verification of Malus's Law using polarizer-analyzer setup.
- Study of Laser Characteristics: Divergence, intensity profile.

Module 4: Material Properties & Applications

- Measurement of Thermal Conductivity of metals (Lee's disc method).
- Study of Hysteresis Loop for ferromagnetic materials.
- Determination of Planck's constant using photoelectric effect.
- Demonstration of Superconductivity using high-Tc superconductor (Meissner effect demo).

SUBJECT CODE: BTAE103

SUBJECT NAME: INTORDUCTION TO AERONAUTICS

Courses Objectives:

- To introduce fundamental principles of aeronautical engineering and aerospace systems.
- To familiarize students with basic aerodynamics, aircraft components, and flight mechanics.
- To provide an overview of aerospace materials, propulsion systems, and aircraft structures.
- To develop awareness of aviation history, aerospace industry, and career opportunities.
- To establish foundation for advanced aerospace engineering courses.

Course Outcomes: At the end of the course students shall be able to

CO1	Explain basic aerodynamics principles and atmospheric properties relevant to flight.
CO2	Identify and describe major aircraft components and their functions in different aircraft configurations.
C03	Analyze basic flight mechanics including forces, stability, and control of aircraft.
C04	Describe fundamental aerospace materials, propulsion

	principles, and structural considerations.

Unit	Content	Credit	Weightage
I	**FUNDAMENTALS OF FLIGHT & HISTORY** • **Introduction to Aeronautics**: Definition, scope, and importance • **History of Aviation**: Early attempts, Wright brothers, milestones in aviation • **Atmosphere and Its Properties**: Standard atmosphere, pressure, temperature, density variations with altitude • **Basic Aerodynamic Concepts**: Airfoil terminology, lift, drag, thrust, weight • **Classification of Aircraft**: Lighter-than-air vs heavier-than-air, fixed-wing vs rotary-wing • **Aerospace Industry Overview**: Civil, military, and space applications • **Career Opportunities in Aerospace**: Roles, sectors, and skill requirements	1	25%
II	**AIRCRAFT COMPONENTS & CONFIGURATIONS** • **Aircraft Major Components**: Fuselage, wings, empennage, landing gear • **Wing Configurations**: Monoplane, biplane, wing placement (high, mid, low) • **Empennage Designs**: Conventional, T-tail, V-tail, cruciform • **Powerplant Installation**: Piston engines, turboprops, jets, placement options • **Cockpit and Control Systems**: Basic flight instruments, control surfaces • **Aircraft Systems Overview**: Hydraulic, pneumatic, electrical, fuel systems • **Special Aircraft**: UAVs/drones, VTOL aircraft, seaplanes	1	25%
III	**BASIC AERODYNAMICS & FLIGHT MECHANICS** • **Air foil Theory**: Basic terminology (chord, camber, thickness), NACA air foils • **Forces on Aircraft**: Four forces of flight, equilibrium conditions • **Lift Generation**: Bernoulli's principle, Newton's laws, angle of attack • **Drag Components**: Parasite drag, induced drag, drag polar • **Stability Concepts**: Static and dynamic stability, longitudinal, lateral, directional • **Control Surfaces**: Ailerons, elevators, rudder, flaps, slats • **Basic Flight Maneuvers**: Takeoff, climb, cruise, descent, landing	1	25%
IV	**AEROSPACE MATERIALS & PROPULSION** • **Aerospace Materials**: Aluminium alloys, titanium, composites, smart materials • **Material Selection Criteria**: Strength-to-weight ratio, fatigue, corrosion resistance	1	25%

	• **Introduction to Propulsion**: Basic principles, thrust generation • **Propulsion Types**: Piston engines, turboprops, turbojets, turbofans • **Rocket Propulsion Basics**: Solid and liquid propellants • **Aircraft Structures**: Semi-monocoque construction, bulkheads, frames, stringers • **Future Trends**: Electric propulsion, sustainable aviation, hypersonics		

TEXT BOOKS:

- "Introduction to Flight" by John D. Anderson Jr. *McGraw-Hill Education, 9th Edition* (Primary Textbook)
- "Aircraft Basic Science" by Michael Kroes, James Rardon, and Michael Nolan *McGraw-Hill Education, 8th Edition*
- "Fundamentals of Aerodynamics" by John D. Anderson Jr.*McGraw-Hill Education, 7th Edition*
- "Jane's All the World's Aircraft" (Latest Edition) *IHS Markit Publications*

REFERENCE BOOKS:

- "The Simple Science of Flight: From Insects to Jumbo Jets" by Henk Tennekes *MIT Press, Revised Edition*
- "Aircraft Design: A Conceptual Approach" by Daniel P. Raymer *AIAA Education Series, 6th Edition*
- "Stick and Rudder: An Explanation of the Art of Flying" by Wolfgang Langewiesche *McGraw-Hill, Reissue Edition*
- "Introduction to Aerospace Engineering with a Flight Test Perspective" by Stephen Corda *Wiley, 1st Edition*
- "Aircraft Structures for Engineering Students" by T.H.G. Megson *Elsevier, 7th Edition*

ONLINE PLATFORMS:

- MIT Open Course Ware: Aerospace Engineering Courses
- Khan Academy: Physics of Flight Modules
- Aerospaceweb.org: Technical Reference
- NPTEL (National Programme on Technology Enhanced Learning):
- "Introduction to Aerospace Engineering" by IIT Kanpur
- "Aircraft Performance and Stability" by IIT Kharagpur
- "Aerospace Materials" by IIT Madras

SUBJECT CODE: BTAE104

SUBJECT NAME: ENGINEERING GRAPHICS AND CAD

Course Objectives:

- To develop spatial visualization skills for interpreting and creating engineering drawings.
- To introduce manual drafting techniques using standard drawing instruments.
- To impart proficiency in Computer-Aided Design (CAD) software for 2D and 3D modeling.
- To apply geometric dimensioning and tolerancing (GD&T) principles in mechanical design.
- To prepare students for creating manufacturing-ready drawings and assemblies.
- To integrate CAD with modern engineering workflows and design thinking.

Course Outcomes: At the end of the course students shall be able to

CO1	Create and interpret engineering drawings using standard conventions (BIS/ISO).
CO2	Construct orthographic, isometric, and sectional views of mechanical components.
C03	Develop 3D solid models and assemblies using CAD software (SolidWorks/AutoCAD).

Unit	Content	Credit	Weightage
I	**FUNDAMENTALS OF ENGINEERING DRAWING** • **Drawing Instruments & Standards:** Use of drawing tools, BIS/ISO standards, sheet layout, title block. • **Lettering & Line Types:** Engineering lettering (single stroke), types of lines (visible, hidden, center, section). • **Geometric Constructions:** Bisection, division of lines, tangency, polygons, conic sections. • **Scales:** Plain, diagonal, vernier scales, scale selection for drawings. • **Dimensioning:** Aligned and unidirectional systems, chain and parallel dimensioning, rules.	1	30%
II	**ORTHOGRAPHIC PROJECTIONS & SECTIONS** • **Projection Principles:** First-angle vs. third-angle projection, projection of points and lines. • **Orthographic Views:** Front, top, side views of simple and complex objects, missing view problems. • **Auxiliary Views:** Primary and secondary auxiliary projections for inclined surfaces. • **Sectional Views:** Full, half, offset, aligned, and broken-out sections, section lining conventions. • **Conventional Practices:** Simplified representation of threads, springs, gears, and welded joints.	1	35%
III	**PICTORIAL & DEVELOPMENT DRAWINGS** • **Isometric Projection:** Isometric axes, isometric scale, construction of isometric views from orthographic. • **Perspective Drawing:** One-point and two-point perspective basics. • **Development of Surfaces:** Parallel-line and radial-line development of prisms, cylinders, cones, and transitions. • **Intersection of Solids:** Interpenetration of cylinders, prisms, and cones, line of intersection. • **Applications:** Sheet metal layouts, ducting, piping, and container design.	1	35%

TEXT BOOKS:

- Engineering Drawing – N.D. Bhatt (Charotar Publishing)
- Engineering Drawing with CAD – M.B. Shah & B.C. Rana (Pearson)
- Engineering Graphics – K.V. Natarajan (SCItech Publications)
- AutoCAD 2023: A Problem-Solving Approach – Sham Tickoo (CADCIM Technologies)

REFERENCE BOOKS:

- Technical Drawing – Giesecke, Mitchell, Spencer (Pearson)
- Engineering Design: A CAD Approach – A. Deane, C. McAdams (Wiley)

- SolidWorks 2023 for Engineers and Designers – Prof. Sham Tickoo (CADCIM)
- Geometric Dimensioning and Tolerancing – James D. Meadows (CRC Press)

LIST OF PRACTICALS:

- Lab 1: Use of drawing instruments, lettering practice, geometric constructions.
- Lab 2: Orthographic projections of simple objects (first-angle projection).
- Lab 3: Orthographic projections of objects with inclined surfaces.
- Lab 4: Sectional views of machine components (full, half, offset sections).
- Lab 5: Isometric drawing from given orthographic views.
- Lab 6: Development of lateral surfaces of prism, cylinder, and cone.
- Lab 7: Introduction to CAD software – basic commands, coordinate input, drawing setup.
- Lab 8: 2D drafting – drawing and editing commands, layers, dimensioning.
- Lab 9: 3D solid modelling – extrude, revolve, Boolean operations.
- Lab 10: Advanced 3D modelling – sweep, loft, shell, fillet, chamfer.
- Lab 11: Assembly modelling – inserting parts, applying mates, interference check.
- Lab 12: Drawing sheet creation – views, annotations, GD&T, BOM, plotting.

SEMESTER-II

SUBJECT CODE: BTAE201

SUBJECT NAME: ENGINEERING MATHAMTICS-II

Course Outcomes: At the end of the course students shall be able to

CO1	**Apply** linear algebra concepts (eigenvalues, SVD) to problems in computer graphics, data compression, and machine learning.
CO2	**Formulate** and **solve** probability models for analysing randomized algorithms, network reliability, and performance evaluation.
C03	**Model** computational problems using graph theory and solve basic graph algorithms relevant to networks and data structures.
C04	**Implement** numerical methods for solving mathematical problems computationally with error analysis awareness.

Unit	Content	Credit	Weightage
I	**Advanced Linear Algebra** • **Vector Spaces:** Definition, subspaces, linear independence, basis, dimension • **Linear Transformations:** Matrix representation, kernel, image, rank-nullity theorem • **Eigenvalues and Eigenvectors:** Computation, properties, diagonalization • **Singular Value Decomposition (SVD):** Geometric interpretation, applications in data science • **Matrix Factorization:** LU, QR decompositions (algorithmic perspective)	1	25%

II	**Probability Theory for Computer Science**
	• **Probability Basics:** Axioms, conditional probability, Bayes' theorem
	• **Random Variables:** Discrete and continuous, PMF/PDF, CDF
	• **Important Distributions:**
	    ○ Discrete: Bernoulli, Binomial, Poisson, Geometric
	    ○ Continuous: Uniform, Normal, Exponential
	• **Expectation and Variance:** Properties, moments
	• **Joint Distributions:** Covariance, correlation, independence
	• **Law of Large Numbers & Central Limit Theorem:** Conceptual understanding
		1	25%

III	**Discrete Mathematics** • **Graph Theory:** Basic terminology, types of graphs, connectivity	1	25%

	• **Special Graphs:** Trees, bipartite graphs, planar graphs • **Graph Algorithms:** Shortest path (conceptual), graph coloring • **Combinatorics:** Counting principles, permutations, combinations • **Recurrence Relations:** Formulation, solving using characteristic equations		
IV	**Numerical Methods for CS Applications** • **Numerical Linear Algebra:** Solving linear systems (Gaussian elimination, iterative methods) • **Numerical Integration:** Trapezoidal rule, Simpson's rule • **Root Finding:** Bisection method, Newton-Raphson method • **Error Analysis:** Round-off error, truncation error, stability	1	25%

Textbooks:

- Linear Algebra and Its Applications by Gilbert Strang (for Module 1)
- Introduction to Probability by Dimitri P. Bertsekas and John N. Tsitsiklis (for Module 2)
- Discrete Mathematics and Its Applications by Kenneth H. Rosen (for Module 3)

Reference books:

- Numerical Recipes by Press et al. (for Module 4)
- Convex Optimization by Boyd and Vandenberghe (for Module 5)
- Mathematics for Computer Science (MIT Open Course Ware)

Digital Resources:

- 3Blue1Brown YouTube series (linear algebra, calculus)
- Khan Academy probability and linear algebra modules

Jupyter notebooks for computational examples

SUBJECT CODE: BTAE202

SUBJECT NAME: ENGINEERING MECHANICS

Course Objectives:

- To introduce the fundamental principles of statics, dynamics, and mechanics of materials.
- To develop analytical skills for solving problems involving forces, equilibrium, and motion.
- To apply principles of mechanics to analyse structures, machines, and mechanical systems.
- To prepare students for advanced courses in solid mechanics, machine design, and dynamics.

Course Outcomes: At the end of the course students shall be able to

CO1	Analyze force systems and compute resultants for particles and rigid bodies.
CO2	Apply equilibrium conditions to solve problems in statics for trusses, beams, and frames.
C03	Determine centroids, moments of inertia, and analyze friction in mechanical systems.
C04	Solve kinematics and kinetics problems for particles and rigid bodies in motion.

Unit	Content	Credit	Weightage
I	STATICS OF PARTICLES & RIGID BODIES Introduction to Mechanics, Force Systems, Resultant of Force Systems, Equilibrium of Particles, Moment of a Force, Rigid Body Equilibrium	1	25%
II	ANALYSIS OF STRUCTURES Trusses, Frames and Machines, Beams, Cables and Arches, Friction	1	25%
III	PROPERTIES OF SURFACES AND DISTRIBUTED FORCES Centroid, Centre of Gravity, Moment of Inertia, Mass Moment of Inertia, Virtual Work	1	25%
IV	DYNAMICS OF PARTICLES AND RIGID BODIES Kinematics of Particles, Kinetics of Particles, Kinematics of Rigid Bodies, Kinetics of Rigid Bodies, Vibrations	1	25%

Textbooks:

- Engineering Mechanics: Statics and Dynamics – R.C. Hibbeler (Pearson)
- Engineering Mechanics – S. S. Bhavikatti and K. G. Rajashekarappa (New Age International)
- Engineering Mechanics: Statics & Dynamics – Irving H. Shames (Prentice Hall)
- Engineering Mechanics: Statics and Dynamics – J.L. Meriam and L.G. Kraige (Wiley)

Reference books:

- Vector Mechanics for Engineers: Statics and Dynamics – Beer and Johnston (McGraw Hill)
- Engineering Mechanics – D.S. Bedi (Khanna Publishers)
- A Textbook of Engineering Mechanics – R.K. Bansal (Laxmi Publications)
- Engineering Mechanics: Problems and Solutions – K. Vijaya Kumar and J. Suresh Kumar (McGraw Hill)
- Advanced Engineering Mechanics – H.C. Gupta (Standard Publishers)

SUBJECT CODE: BTAE203

SUBJECT NAME: INTORDUCTION TO AERONAUTICS

Courses Objectives:

- To develop fundamental programming skills using Python with aerospace applications
- To introduce computational thinking and algorithm development for engineering problems
- To teach data structures, file handling, and numerical methods relevant to aerospace engineering
- To prepare students for advanced courses in computational aerodynamics and flight simulation
- To integrate programming with aerospace engineering problems through practical applications

Course Outcomes: At the end of the course students shall be able to

CO1	Develop and implement algorithms using Python for basic engineering computations
CO2	Apply control structures, functions, and modular programming to solve aerospace problems
C03	Implement and use data structures (arrays, lists, dictionaries) for handling aerospace data
C04	Develop Python programs for aerospace applications including trajectory calculations and data analysis

Unit	Content	Credit	Weightage

I	**PROGRAMMING FUNDAMENTALS & AEROSPACE APPLICATIONS**
	• **Introduction to Programming**: Algorithms, flowcharts, pseudocode
	• **Python Basics**: Installation, IDEs (Spyder/Jupyter), syntax, variables, data types
	• **Operators and Expressions**: Arithmetic, relational, logical operators
	• **Input/Output Operations**: Reading keyboard input, formatted output
	• **Basic Aerospace Applications**:
	  ○ Atmospheric property calculations (pressure, density vs altitude)
	  ○ Unit conversions (knots to kmph, feet to meters)
	  ○ Basic flight parameter calculations
	• **Introduction to C++**: Basic syntax and comparison with Python
		1	25%

II	**CONTROL STRUCTURES & FUNCTIONS FOR ENGINEERING**
	• **Decision Making**: if, if-else, nested if, elif statements
	• **Looping Structures**: for loops, while loops, nested loops
	• **Break, Continue, Pass statements**
	• **Functions**: Definition, parameters, return values, scope
	• **Modular Programming**: Creating reusable code modules
	• **Aerospace Applications**:
	  ○ Flight phase analysis (takeoff, cruise, landing conditions)
	  ○ Aircraft performance range calculations
	  ○ Wind correction angle computations
	  ○ Fuel consumption calculations
		1	25%

III	**DATA STRUCTURES & FILE HANDLING FOR AEROSPACE DATA**
	• **Lists**: Creation, indexing, slicing, list methods
	• **Tuples and Sets**: Characteristics and operations
	• **Dictionaries**: Key-value pairs, methods, applications
	• **Arrays using NumPy**: Creation, operations, mathematical functions
	• **File Handling**: Reading/writing text files, CSV files
	• **Aerospace Applications**:
	  ○ Storing and processing flight test data
	  ○ Aircraft configuration databases
	  ○ Meteorological data processing
	  ○ Air foil coordinate data handling
		1	25%

IV	**ADVANCED APPLICATIONS & NUMERICAL METHODS** • **Introduction to Object-Oriented Programming**: Classes, objects, methods • **Numerical Methods Basics**: Root finding, interpolation,	1	25%

	numerical integration • **Data Visualization**: Introduction to Matplotlib for plotting • **Scientific Computing**: Using SciPy for engineering computations • **Aerospace Applications**: ○ Trajectory calculations ○ Aerodynamic coefficient interpolation ○ Basic stability derivative calculations ○ Performance envelope plotting • **Introduction to C++ for Performance**: Basic I/O, loops, functions in C++		

TEXT BOOKS:
- "Python Programming: Using Problem Solving Approach" by Reema Thareja
  Oxford University Press
- "Introduction to Programming in Python: An Interdisciplinary Approach" by Robert Sedgewick, Kevin Wayne, and Robert Dondero
  Addison-Wesley Professional
- "A Primer on Scientific Programming with Python" by Hans Petter Langtangen
  Springer, 5th Edition

REFERENCE BOOKS:
- "Python for Engineers and Scientists" by Rakesh Nayak and Nishu Gupta *CRC Press*
- "Python and Matplotlib Essentials for Scientists and Engineers" by Matt A. Wood
  Morgan & Claypool Publishers
- "Numerical Python: Scientific Computing and Data Science Applications with Numpy, SciPy and Matplotlib" by Robert Johansson *Apress, 2nd Edition*
- "C++ for Engineers and Scientists" by Gary J. Bronson *Cengage Learning*
- "Programming and Problem Solving with C++" by Nell Dale and Chip Weems
  Jones & Bartlett Learning

ONLINE PLATFORMS:

NPTEL (National Programme on Technology Enhanced Learning):
- "Programming, Data Structures and Algorithms using Python" by IIT Madras
- "Problem Solving through Programming in C" by IIT Kharagpur
- "Introduction to Programming in C++" by IIT Bombay

Coursera:
- "Python for Everybody" by University of Michigan
- "Python Data Structures" by University of Michigan
- "Scientific Computing with Python" by freeCodeCamp
- "C++ For C Programmers" by University of California, Santa Cruz

PRACTICAL LIST:

Session 1: Environment Setup & Basic Operations • Installation of Python and development environment • Write a program to calculate aircraft Mach number from true airspeed and altitude	Session 7: Numerical Computations • Implement bisection method for root finding in aerodynamic equations • Numerical integration for area calculations • Linear interpolation for

- Develop a program for unit conversions common in aviation
- Calculate standard atmospheric properties at given altitude

Session 2: Control Structures in Aerospace Context

- Program to determine flight phase based on altitude and airspeed
- Calculate aircraft range with different fuel loads using loops
- Develop a program to compute takeoff distance under various conditions
- Wind triangle calculations for navigation

Session 3: Functions for Modular Design

- Create a function library for atmospheric calculations
- Develop a module for aircraft performance calculations
- Implement a stall speed calculator function
- Create reusable functions for geometric calculations (wing area, aspect ratio)

Session 4: Lists and Arrays for Flight Data

- Store and process time-series flight data
- Calculate statistical parameters from flight test data
- Implement moving average filter for noisy sensor data
- Process airfoil coordinate data from files

Session 5: Dictionaries for Aircraft Databases

- Create an aircraft database using dictionaries
- Develop a program to retrieve aircraft specifications
- Implement a weather data processing system
- Create a navigation waypoint database

Session 6: File Handling for Aerospace Applications

- Read and process CSV files containing flight data

aerodynamic tables

- Solve systems of linear equations for stability derivatives

Session 8: Data Visualization

- Plot aircraft trajectory in 2D and 3D
- Create performance charts (V-n diagram, drag polar)
- Visualize pressure distribution over airfoil
- Generate time-history plots of flight parameters

Session 9: Object-Oriented Programming

- Create a class for Aircraft with properties and methods
- Implement inheritance for different aircraft types
- Develop a Flight class to manage flight operations
- Create a Sensor class for instrument simulations

Session 10: Trajectory Simulation

- Develop a simple projectile trajectory simulator
- Implement basic aircraft climb performance calculation
- Create a glider performance calculator
- Simulate orbital mechanics basics

Session 11: Introduction to C++ for Performance

- Basic I/O operations in C++
- Implement aerospace calculations in C++
- Compare performance of Python vs C++ for numerical computations
- Create hybrid Python-C++ applications

Session 12: Mini Project

Choose one of the following:

- Aircraft Performance Calculator: Comprehensive tool for basic performance analysis
- Atmospheric Properties Calculator: With visualization and data export

• Write computed results to formatted text files • Process NACA airfoil data files • Create log files for simulation results	• Flight Data Analyzer: Process and visualize experimental data Basic Flight Simulator: Simple 2D aircraft dynamics simulation

SUBJECT CODE: BTAE204

SUBJECT NAME: MATERIAL SCIENCE FOR AEROSPACE

Courses Objectives:

- To introduce fundamental concepts of materials science relevant to aerospace applications
- To understand the relationship between material structure, properties, and performance in aerospace environments
- To study advanced aerospace materials including composites, superalloys, and ceramics
- To analyze material selection criteria for different aerospace components and structures
- To develop awareness of material degradation, failure mechanisms, and inspection techniques in aerospace

Course Outcomes: At the end of the course students shall be able to

CO1	Explain crystal structures, defects, and phase diagrams relevant to aerospace alloys
CO2	Analyze mechanical properties and failure mechanisms of aerospace materials
C03	Evaluate and select appropriate materials for specific aerospace applications
C04	Describe advanced aerospace materials, their processing, and testing methods

Unit	Content	Credit	Weightage
I	**FUNDAMENTALS & AEROSPACE ALLOYS** • **Introduction to Aerospace Materials**: Historical perspective, material requirements for aerospace • **Atomic Structure & Bonding**: Metallic, covalent, ionic bonding in aerospace materials • **Crystal Structures**: BCC, FCC, HCP structures, crystallographic notation • **Crystal Defects**: Point, line, surface defects and their significance • **Phase Diagrams**: Binary phase diagrams, iron-carbon diagram, aluminum alloys • **Aerospace Aluminum Alloys**: 2XXX, 6XXX, 7XXX series, heat treatment (T6, T7) • **Titanium Alloys**: Alpha, alpha-beta, beta alloys, applications in aerospace	1	25%

	• **Magnesium Alloys**: Lightweight applications, limitations		
II	**MECHANICAL PROPERTIES & FAILURE MECHANISMS** • **Mechanical Properties**: Stress-strain curves, elastic/plastic deformation • **Strength Parameters**: Yield strength, ultimate strength, fracture toughness • **Fatigue in Aerospace**: High-cycle and low-cycle fatigue, S-N curves • **Fracture Mechanics**: Griffith theory, stress intensity factor, fracture toughness • **Creep & Stress Rupture**: Mechanisms, Larson-Miller parameter • **Corrosion in Aerospace**: Types (galvanic, pitting, stress corrosion cracking) • **Environmental Effects**: Temperature extremes, radiation, atomic oxygen in space • **Material Testing Methods**: Tensile, hardness, impact, fatigue testing	1	25%
III	**COMPOSITE MATERIALS FOR AEROSPACE** • **Introduction to Composites**: Advantages, classification, aerospace applications • **Reinforcements**: Glass fibers, carbon fibers, aramid fibers, ceramic fibers • **Polymer Matrix Composites (PMCs)**: Epoxy, polyester, phenolic resins • **Metal Matrix Composites (MMCs)**: Aluminum, titanium, magnesium matrix composites • **Ceramic Matrix Composites (CMCs)**: Silicon carbide, carbon-carbon composites • **Composite Manufacturing**: Hand lay-up, autoclave, RTM, filament winding • **Mechanics of Composites**: Rule of mixtures, lamina properties, laminate theory • **Damage in Composites**: Delamination, impact damage, NDT techniques	1	25%

IV	**SPECIALTY MATERIALS & MATERIALS SELECTION**
	• **Superalloys**: Nickel-based superalloys for gas turbine engines
	• **Refractory Materials**: Tungsten, molybdenum, niobium alloys
	• **Ceramics & Cermets**: Applications in thermal protection systems
	• **Smart Materials**: Shape memory alloys, piezoelectric materials
	• **Coatings & Surface Treatments**: Thermal barrier coatings, anodizing, plasma spraying
	• **Material Selection Methodology**: Ashby charts, performance indices
	• **Aerospace Applications**:
	  ○ Engine materials (compressor, turbine, combustor)
	  ○ Airframe materials (fuselage, wings, control surfaces)
	  ○ Spacecraft materials (thermal protection, radiation shielding) **Emerging Materials**: Nanocomposites,
		1	25%

	graphene, additive manufacturing materials			

TEXT BOOKS:

- "Aerospace Materials and Applications" by Biliyar N. Bhat and S. R. Schmidt *AIAA Education Series, 2018*
- "Introduction to Aerospace Materials" by Adrian P. Mouritz *Woodhead Publishing, 2012*
- "Materials Science and Engineering: An Introduction" by William D. Callister Jr. and David G. Rethwisch *Wiley, 10th Edition*

REFERENCE BOOKS:

- "Aerospace Structures and Materials" by Y. C. Fung and E. E. Sechler *Prentice Hall*
- "Composite Materials for Aircraft Structures" by A. A. Baker, S. Dutton, and D. Kelly *AIAA Education Series, 3rd Edition*
- "Superalloys: A Technical Guide" by Matthew J. Donachie and Stephen J. Donachie *ASM International, 2nd Edition*
- "Engineering Materials 1: An Introduction to Properties, Applications and Design" by Michael F. Ashby and David R. H. Jones *Butterworth-Heinemann, 5th Edition*
- "Fracture Mechanics: Fundamentals and Applications" by T. L. Anderson *CRC Press, 4th Edition*

ONLINE PLATFORMS:

NPTEL (National Programme on Technology Enhanced Learning):

- "Materials Science and Engineering" by IIT Kanpur
- "Composite Materials" by IIT Madras
- "Corrosion Science" by IIT Bombay
- "Fracture Mechanics" by IIT Kharagpur
- Website: https://nptel.ac.in

SUBJECT CODE: BTAE205

SUBJECT NAME: WORKSHOP PRACTICE

Course Objectives:

- To provide hands-on experience with basic workshop tools, machines, and processes.
- To develop skills in measuring, marking, cutting, shaping, and joining engineering materials.
- To introduce manufacturing processes such as casting, machining, welding, and sheet metal work.
- To foster safety awareness and proper handling of workshop equipment.
- To prepare students for practical implementation of mechanical designs and prototypes.

Course Outcomes: At the end of the course students shall be able to

CO1	Operate basic hand tools, measuring instruments, and workshop machinery safely.
CO2	Perform fundamental workshop processes such as fitting, carpentry, welding, and machining.
C03	Fabricate simple components using processes like casting, forging, sheet metal work, and turning.
C04	Assemble components and produce small mechanical assemblies or prototypes.
CO5	Interpret engineering drawings and convert them into physical components.

PRACTICAL LIST (12 Sessions):

Session 1: Workshop Safety & Measurement

Session 2: Fitting – Marking & Sawing

- Objective: Learn marking tools and hand sawing.
- Tasks:
    1. Use of scriber, center punch, surface gauge, and angle plate.
    2. Cutting mild steel flats using hacksaw.
    3. Filing practice (flat, square, and cross filing).
- Deliverable: A marked and sawn MS piece with dimensional accuracy.

Session 3: Fitting – Drilling & Tapping

- Objective: Perform drilling and thread cutting.
- Tasks:
    1. Use of bench drill machine, drill bits, and reamers.
    2. Drill holes on MS plate and deburr.
    3. Tap internal threads and cut external threads using dies.
- Deliverable: Drilled and tapped component.

Session 4: Carpentry – Wood Working

- Objective: Basic woodworking skills.
- Tasks:
    1. Use of saws, planes, chisels, and mallet.
    2. Make a half-lap joint or mortise-tenon joint.
    3. Sanding and finishing of wooden piece.
- Deliverable: A finished wooden joint.

Session 5: Welding – Arc Welding

Session 7: Sheet Metal Work

- Objective: Fabricate sheet metal components.
- Tasks:
    1. Use of snips, stakes, mallets, and folding machines.
    2. Develop a rectangular tray or funnel from GI sheet.
    3. Seaming and riveting practice.
- Deliverable: A sheet metal component (e.g., tray, box).

Session 8: Casting – Sand Molding

- Objective: Understand foundry processes.
- Tasks:
    1. Preparation of green sand, molding tools.
    2. Make a split mold using pattern (single piece).
    3. Pour molten metal (demonstration) and inspect casting.
- Deliverable: A sand mold ready for pouring.

Session 9: Forging

- Objective: Basic hot forging operations.
- Tasks:
    1. Use of forge furnace, anvil, hammers, and tongs.
    2. Perform operations: upsetting, drawing, bending, punching.
    3. Forge a simple component like a chisel or round-to-square.
- Deliverable: A forged component.

Session 10: Machining – Lathe Operation

- Objective: Perform basic lathe operations.
- Tasks:
    1. Identify lathe parts, tool holders, chucks.
    2. Perform facing, turning, step turning, and taper turning.
    3. Practice knurling and parting-off.
- Deliverable: A turned MS component with steps.

Session 11: Machining – Shaping & Milling

- Objective: Use shaping and milling machines.

• Objective: Introduction to electric arc welding. • Tasks: 1. Setting up arc welding machine and electrodes. 2. Practice bead formation on MS plate. 3. Make a lap joint or butt joint. • Deliverable: A welded joint, inspect for defects. **Session 6: Welding – Gas Welding** • Objective: Learn gas welding (oxy-acetylene). • Tasks: 1. Set up gas welding kit, adjust flame (neutral, oxidizing, carburizing). 2. Practice bead on plate, butt joint. 3. Perform brazing of two metal pieces. • Deliverable: Brazed assembly.	• Tasks: 1. Perform plain shaping to produce a flat surface. 2. Use vertical milling machine for slot cutting or face milling. • Deliverable: A machined block with milled slot/shaped surface. **Session 12: Assembly Practice** • Objective: Assemble multiple components into a working model. • Tasks: 1. Use fasteners (nuts, bolts, screws) to assemble parts made in earlier sessions. 2. Assemble a small tool (e.g., bench vice model, paper cutter, clamp). 3. Check alignment, fit, and function. • Deliverable: A fully assembled working model.

SEMESTER-III

SUBJECT CODE: BTAE301

SUBJECT NAME: FLUID MECHANICS

Course Objectives:

- To understand the fundamental properties and behaviour of fluids under static and dynamic conditions.
- To apply principles of fluid statics, kinematics, and dynamics to solve engineering problems.
- To analyse flow behaviour using continuity, momentum, and energy equations.
- To study flow measurement techniques, boundary layer theory, and drag/lift forces.
- To prepare students for applications in hydraulic machinery, piping systems, and fluid system design.

Course Outcomes: At the end of the course students shall be able to

CO1	Analyze fluid properties and hydrostatic forces on submerged surfaces.
CO2	Apply continuity, momentum, and energy equations to fluid flow problems.
C03	Classify fluid flow and analyze flow through pipes, ducts, and open channels.
C04	Evaluate boundary layer effects, drag, lift, and performance of hydraulic machines.

Unit	Content	Credit	Weightage
I	FLUID PROPERTIES & FLUID STATICS Introduction to Fluid Mechanics, Fluid Properties, Fluid Statics, Hydrostatic Forces Fluid Kinematics	1	25%
II	FLUID DYNAMICS & BASIC EQUATIONS Conservation Laws, Bernoulli's Equation, Energy Equation, Momentum Equation, Dimensional Analysis & Similitude	1	25%
III	FLOW THROUGH PIPES & DUCTS Flow Classification, Laminar Flow, Turbulent Flow, Pipe Flow Analysis, Boundary Layer Theory	1	25%
IV	FLOW MEASUREMENT & HYDRAULIC MACHINERY Flow Measurement Devices, Drag and Lift, Introduction to Compressible Flow, Hydraulic Machines – Pumps, Hydraulic Machines	1	25%

Textbooks:

- Fluid Mechanics – Frank M. White (McGraw Hill)
- Introduction to Fluid Mechanics and Fluid Machines – S.K. Som and G. Biswas (McGraw Hill)
- Fluid Mechanics and Hydraulic Machines – R.K. Bansal (Laxmi Publications)
- Engineering Fluid Mechanics – K.L. Kumar (S. Chand)

Reference books:

- Fluid Mechanics: Fundamentals and Applications – Yunus A. Çengel and John M. Cimbala (McGraw Hill)
- A Textbook of Fluid Mechanics and Hydraulic Machines – R.K. Rajput (S. Chand)
- Fluid Mechanics – Pijush K. Kundu and Ira M. Cohen (Academic Press)

- Fox and McDonald's Introduction to Fluid Mechanics – Robert W. Fox, Alan T. McDonald, Philip J. Pritchard (Wiley)
- Hydraulics and Fluid Mechanics – P.N. Modi and S.M. Seth (Standard Book House)

Online Platforms:

NPTEL Courses:

- "Fluid Mechanics" by Prof. S.K. Som (IIT Kharagpur)
- "Applied Fluid Mechanics" by IIT Roorkee

SUBJECT CODE: BTAE302

SUBJECT NAME: THERMODYNAMICS

Course Objectives:

- To understand the fundamental concepts, laws, and principles of thermodynamics.
- To analyse thermodynamic properties of pure substances and apply property tables/charts.
- To evaluate thermodynamic cycles (power, refrigeration, heat pump) and their performance.
- To develop problem-solving skills for energy conversion, transfer, and utilization in mechanical systems.
- To apply thermodynamic principles to real-world engineering applications (IC engines, power plants, HVAC).

Course Outcomes: At the end of the course students shall be able to

CO1	Apply the zeroth and first laws of thermodynamics to closed and open systems.
CO2	Analyze the properties of pure substances using tables, charts, and equations of state.
C03	Apply the second law to evaluate entropy, irreversibility, and cycle efficiency.
C04	Analyze and design basic power, refrigeration, and heat pump cycles.

Unit	Content	Credit	Weightage
I	BASIC CONCEPTS & ZEROTH LAW Introduction to Thermodynamics, Thermodynamic Properties, Processes & Cycles, Zeroth Law of Thermodynamics, Work & Heat	1	25%
II	FIRST LAW OF THERMODYNAMICS First Law for Closed Systems, First Law for Open Systems, Energy Analysis of Engineering Devices, Thermodynamic Properties of Pure Substances Equations of State	1	25%
III	SECOND LAW OF THERMODYNAMICS Limitations of First Law, Kelvin-Planck & Clausius Statements, Carnot Cycle, Entropy, Irreversibility & Exergy	1	25%
IV	THERMODYNAMIC CYCLES & APPLICATIONS Gas Power Cycles, Vapor Power Cycles, Refrigeration Cycles, Heat Pump Cycles, Psychrometric	1	25%

Textbooks:

- Engineering Thermodynamics – P.K. Nag (McGraw Hill)
- Thermodynamics: An Engineering Approach – Yunus A. Çengel and Michael A. Boles (McGraw Hill)

- Engineering Thermodynamics – D.S. Kumar (S.K. Kataria & Sons)
- Thermodynamics – J.P. Holman (McGraw Hill)

Reference books:

- Fundamentals of Engineering Thermodynamics – Michael J. Moran and Howard N. Shapiro (Wiley)
- Thermodynamics – R.K. Rajput (Laxmi Publications)
- Applied Thermodynamics – T.D. Eastop and A. McConkey (Pearson)
- Thermodynamics and Heat Engines – R. Yadav (Central Publishing House)
- Thermodynamic Cycles: Computer-Aided Design and Optimization – Chih Wu (CRC Press)

Online Platforms:

1. **NPTEL Courses:**
   - "Applied Thermodynamics" by Prof. S.K. Som (IIT Kharagpur)
   - "Thermodynamics" by Prof. M. Ramgopal (IIT Kharagpur)

SUBJECT CODE: BTAE303

SUBJECT NAME: AIRCRAFT STRUCTURES-I

Course Objectives:

- To introduce fundamental principles of aircraft structural analysis and design
- To understand different types of aircraft structures and their load-carrying mechanisms
- To analyze stress, strain, and deformation in aircraft structural components
- To develop skills in analyzing thin-walled structures and structural joints
- To prepare students for advanced courses in aircraft structural design and fatigue analysis

Course Outcomes: At the end of the course students shall be able to

CO1	Analyze aircraft structural components under various loading conditions
CO2	Determine stresses and deformations in thin-walled aircraft structures
C03	Evaluate structural stability and buckling behavior of aircraft components
C04	Design and analyze aircraft structural joints and connections

Unit	Content	Credit	Weightage

I	**INTRODUCTION TO AIRCRAFT STRUCTURES & LOADS**
	• **Historical Development**: Evolution of aircraft structural design
	• **Aircraft Structural Components**: Fuselage, wings, empennage, control surfaces
	• **Structural Configurations**: Truss, monocoque, semi-monocoque construction
	• **Materials in Aircraft Structures**: Aluminum alloys, composites, titanium
	• **Aircraft Loads**:
	  ○ Air loads (aerodynamic forces)
	  ○ Inertia loads (acceleration forces)
		1	25%

	○ Ground loads (landing, taxiing) ○ Special loads (pressurization, bird strike) • **Load Factors**: Gust loads, maneuver loads, limit and ultimate loads • **V-n Diagram**: Flight envelope and structural limits • **Structural Safety Factors**: Factor of safety, proof load, ultimate load		
II	**ANALYSIS OF THIN-WALLED STRUCTURES** • **Thin-Walled Beam Theory**: Assumptions and limitations • **Shear Flow in Closed Sections**: Bredt-Batho formula • **Shear Center**: Determination for open and closed sections • **Torsion of Thin-Walled Sections**: ○ Open sections (Saint-Venant torsion) ○ Closed sections (Bredt-Batho theory) ○ Multi-cell sections • **Warping in Thin-Walled Beams**: Concept and significance • **Shear Lag Phenomenon**: Effect on stress distribution • **Aircraft Applications**: ○ Wing box analysis ○ Fuselage shell analysis ○ Control surface torsion boxes	1	25%
III	**BUCKLING & STABILITY OF AIRCRAFT STRUCTURES** • **Column Buckling**: Euler buckling formula for various end conditions • **Effective Length Concept**: For different boundary conditions • **Local Buckling**: Plate and shell buckling • **Critical Buckling Stress**: For plates under compression and shear • **Stiffened Panels**: Stringer-stiffened panels, waffle panels • **Post-Buckling Strength**: Behavior after initial buckling • **Crippling of Thin Sections**: Failure of thin-walled columns • **Aircraft Applications**: ○ Wing skin buckling analysis ○ Fuselage panel stability ○ Rib and frame design for buckling prevention	1	25%
IV	**JOINTS & CONNECTIONS IN AIRCRAFT STRUCTURES**	1	25%

	• **Types of Aircraft Joints**:
	  ○ Bolted joints (shear, tension, bearing)
	  ○ Riveted joints
	  ○ Bonded joints (adhesive bonding)
	  ○ Welded joints (spot welding, TIG welding)
	• **Stress Analysis of Joints**:
	  ○ Load distribution in multi-fastener joints
	  ○ Eccentrically loaded joints
	  ○ Fatigue considerations in joints
	• **Failure Modes**:
	  ○ Shear failure of fasteners
	  ○ Bearing failure of sheets
	  ○ Net-section failure
	  ○ Tear-out failure
	• **Joint Efficiency**: Factors affecting joint strength
	• **Special Connections**:
	  ○ Wing-fuselage attachments
	  ○ Engine mounts
	  ○ Landing gear attachments
	  ○ Control surface hinges
	• **Repair Considerations**: Damage tolerance, repairability		

Textbooks:

- "Aircraft Structures for Engineering Students" by T.H.G. Megson *Elsevier, 7th Edition*
- "Analysis of Aircraft Structures: An Introduction" by Bruce K. Donaldson *Cambridge University Press, 2nd Edition*
- "Introduction to Aircraft Structural Analysis" by David J. Peery and J.J. Azar *Dover Publications*

Reference books:

- "Theory and Analysis of Flight Structures" by Robert M. Rivello *McGraw-Hill*
- "Airframe Stress Analysis and Sizing" by Michael C.Y. Niu *Hong Kong Commilit Press, 3rd Edition*
- "Structural Analysis: With Applications to Aerospace Structures" by Bruce K. Donaldson *Springer*
- "Aircraft Design: A Conceptual Approach" by Daniel P. Raymer *AIAA Education Series, 6th Edition*
- "Bruhn's Analysis and Design of Flight Vehicle Structures" by E.F. Bruhn *Jacobs Publishing*
- "Handbook of Structural Life Assessment" by Raheem M.A. *Wiley*

Online Platforms:

NPTEL (National Programme on Technology Enhanced Learning):

- "Aircraft Structures" by IIT Kharagpur
- "Structural Analysis" by IIT Madras
- "Finite Element Analysis" by IIT Kanpur
- "Aircraft Design" by IIT Bombay

PRACTICAL LIST:

Session 1: Material Properties Determination	Session 7: Column Buckling Experiment

- Tensile test of aerospace aluminum alloy (2024-T3)
- Determination of Young's modulus, yield strength, ultimate strength
- Calculation of Poisson's ratio from strain measurements
- Comparison with aerospace material specifications (AMS standards)

Session 2: Beam Bending Analysis

- Three-point bending test of aircraft spar specimen
- Calculation of bending stress distribution
- Deflection measurement and comparison with theoretical values
- Stress concentration factors at cutouts

Session 3: Torsion Testing

- Torsion test of thin-walled tube (simulating aircraft structural member)
- Measurement of angle of twist vs applied torque
- Calculation of shear modulus
- Comparison of open vs closed section torsional stiffness

Session 4: Shear Center Determination

- Experimental determination of shear center for channel section
- Calculation of shear flow distribution
- Comparison with theoretical predictions
- Application to aircraft wing rib design

Session 5: Thin-Walled Beam Analysis

- Load distribution in multi-cell wing box model
- Shear flow analysis using strain gauge measurements
- Torsional stiffness measurement
- Warping effects observation

Session 6: Composite Laminate Analysis

- Preparation of simple composite laminate
- Determination of laminate properties
- Comparison with metallic structure properties

Failure modes in composite structures

- Euler buckling test of slender columns
- Effect of end conditions on buckling load
- Comparison of experimental vs theoretical buckling loads
- Determination of effective length factors

Session 8: Plate Buckling Analysis

- Buckling test of thin aluminum plates under compression
- Observation of buckling modes (half-wave, full-wave)
- Effect of edge constraints on buckling load
- Post-buckling strength measurement

Session 9: Stiffened Panel Analysis

- Testing of stringer-stiffened panel under compression
- Comparison of buckling loads with unstiffened panel
- Local vs global buckling observation
- Crippling strength determination

Session 10: Joint Analysis

- Tensile test of single lap joint
- Shear test of multi-rivet joint
- Failure mode analysis (shear, bearing, net-section)
- Joint efficiency calculation

Session 11: Introduction to FEA Software

- Basic modeling of simple beam in ANSYS
- Static analysis of cantilever beam
- Stress and deformation visualization
- Comparison with analytical solutions

Session 12: Aircraft Component Analysis Project
Choose one of the following:

- Wing Rib Analysis: Stress analysis of a typical wing rib
- Fuselage Frame Analysis: Load analysis of fuselage frame
- Landing Gear Attachment: Stress analysis of mounting brackets

SUBJECT CODE: BTAE304

SUBJECT NAME: AEROSPACE MATERIALS

Course Objectives:

- To provide comprehensive knowledge of advanced materials used in aerospace applications
- To understand material behavior under extreme aerospace environments (high temperature, cryogenic, vacuum)
- To study material selection criteria for specific aerospace components and systems
- To analyze material degradation, life prediction, and failure analysis in aerospace
- To explore emerging materials and technologies in aerospace applications

Course Outcomes: At the end of the course students shall be able to

CO1	Analyze material requirements for different aerospace applications and environments
CO2	Evaluate advanced aerospace materials for specific component applications
C03	Apply material selection methodology using performance indices and Ashby charts
C04	Assess material degradation mechanisms and predict service life in aerospace environments

Unit	Content	Credit	Weightage
I	**ADVANCED AEROSPACE ALLOYS & SUPERALLOYS** High-Temperature Materials Nickel-Based Superalloys Cobalt-Based Superalloys Cobalt-Based Superalloys: Properties and applications Titanium Aluminides: TiAl and Ti_3Al intermetallics Refractory Metals aluminium-Lithium Alloys: Reduced density, improved stiffness Applications in modern aircraft structures Advanced Magnesium Alloys: Creep-resistant varieties Material Testing at Elevated Temperatures: Creep, stress rupture testing	1	25%
II	**AEROSPACE COMPOSITES & HYBRID MATERIALS** Advanced Polymer Matrix Composites (PMCs) Metal Matrix Composites (MMCs) Ceramic Matrix Composites (CMCs) Hybrid Materials Smart Composites Manufacturing Advances	1	25%

III	**SPECIALTY MATERIALS FOR SPACE & EXTREME ENVIRONMENTS** Space Environment Effects Thermal Protection Systems (TPS) Cryogenic Materials Radiation Shielding Materials Transparent Materials Sealants and Coatings Additive Manufacturing Materials	1	25%
IV	**MATERIALS SELECTION & LIFE MANAGEMENT** **Systematic Material Selection**: Performance indices method (Ashby charts) Weighted property indices Cost-performance trade-offs **Case Studies in Material Selection**: Wing skin materials (aluminium vs composites) Engine turbine blade materials Spacecraft structural materials Hypersonic vehicle materials **Damage Tolerance and Durability**: Fatigue crack growth analysis, Corrosion fatigue, Environmental degradation **Non-Destructive Evaluation (NDE)**: Advanced NDT techniques (thermography, shearography, acoustic emission) Structural health monitoring (SHM) systems **Repair and Maintenance Materials**: Bonded repair technology Composite patch repairs Corrosion repair materials **Life Prediction and Extension**: Damage accumulation models Retirement-for-cause methodology Remaining life assessment **Emerging Materials**: Graphene and 2D materials Metamaterials Bio-inspired materials Self-adaptive materials	1	25%

Textbooks:

- "Aerospace Materials and Applications" by Biliyar N. Bhat, S. R. Schmidt, and NASA Technical Team
  AIAA Education Series, 2018
- "Structural Materials: Properties and Selection" by Kenneth G. Budinski and Michael K. Budinski
  Pearson, 9th Edition
- "Advanced Aerospace Materials" by H. Bühler and H. G. J. J. K. S. F. K. L. M. (Eds.)
  Springer-Verlag

Reference books:

- "ASM Handbook, Volume 21: Composites" by ASM International *ASM International*

- "Superalloys: A Technical Guide" by Matthew J. Donachie and Stephen J. Donachie *ASM International, 2nd Edition*
- "High Temperature Materials for Aerospace" by R. H. B. R. C. D. E. F. G. (Ed.) *John Wiley & Sons*
- "Materials Selection in Mechanical Design" by Michael F. Ashby *Butterworth-Heinemann, 5th Edition*
- "Space Materials Handbook" by John W. Lucas *Lockheed Missiles & Space Company*
- "Composite Materials for Aircraft Structures" by A. A. Baker, S. Dutton, and D. Kelly *AIAA Education Series, 3rd Edition*

Online Platforms:

- Coursera:
  - "Materials Science and Engineering" - Georgia Tech
  - "The Science of Superalloys" - École des Mines de Nancy
  - "Composite Materials" - University of Washington
- NPTEL (Indian Platform):
  - "Advanced Aerospace Materials" - IIT Madras
  - "Composite Materials and Structures" - IIT Kharagpur
  - "High Temperature Materials" - IIT Bombay

SUBJECT CODE: BTAE305

SUBJECT NAME: INTRODUCTION TO AI/ML

Course Objectives:

- To introduce fundamental concepts of Artificial Intelligence and Machine Learning relevant to aerospace applications
- To develop skills in implementing ML algorithms for aerospace data analysis and prediction
- To apply AI/ML techniques to solve practical aerospace engineering problems
- To prepare students for advanced courses in computational aerodynamics, autonomous systems, and aerospace data science
- To understand ethical considerations and limitations of AI in aerospace applications

Course Outcomes: At the end of the course students shall be able to

CO1	Apply fundamental AI/ML concepts and techniques to aerospace datasets
CO2	Implement supervised and unsupervised learning algorithms for aerospace applications
C03	Develop and evaluate machine learning models for flight data analysis and prediction
C04	Design AI solutions for specific aerospace engineering problems using appropriate ML techniques

Unit	Content	Credit	Weightage
I	FOUNDATIONS OF AI & DATA PREPROCESSING FOR AEROSPACE Introduction to AI/ML in Aerospace, Python for AI/ML, Aerospace Data Characteristics, Data Preprocessing, Exploratory Data Analysis (EDA), Introduction to Scikit-	1	25%

	learn		
II	SUPERVISED LEARNING FOR AEROSPACE APPLICATIONS Regression Algorithms, Classification Algorithms, Model Evaluation, Cross-validation, Hyperparameter Tuning, Aerospace Applications	1	25%
III	ADVANCED ML TECHNIQUES & UNSUPERVISED LEARNING Ensemble Methods, Support Vector Machines (SVM), Unsupervised Learning, Anomaly Detection, Aerospace Applications	1	25%
IV	NEURAL NETWORKS & DEEP LEARNING FOR AEROSPACE Introduction to Neural Networks, Deep Learning Frameworks, Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs), Transfer Learning, Ethical Considerations, Emerging Applications	1	25%

Textbooks:

- "Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow" by Aurélien Géron *O'Reilly Media, 3rd Edition*
- "Python Machine Learning" by Sebastian Raschka and Vahid Mirjalili *Packt Publishing, 3rd Edition*
- "Machine Learning for Aerospace" (Custom compilation of aerospace case studies)

Reference books:

- "Pattern Recognition and Machine Learning" by Christopher M. Bishop *Springer, 2006*
- "Deep Learning" by Ian Goodfellow, Yoshua Bengio, and Aaron Courville *MIT Press, 2016*
- "Machine Learning Yearning" by Andrew Ng *Online Book*
- "Artificial Intelligence: A Modern Approach" by Stuart Russell and Peter Norvig *Pearson, 4th Edition*
- "Data Science for Business" by Foster Provost and Tom Fawcett *O'Reilly Media*
- "Flight Data Monitoring and Analysis: Applications of AI and ML" by Various Authors *SAE International*

Online Platforms:

Coursera:

- "Machine Learning" by Andrew Ng (Stanford University)
- "Deep Learning Specialization" by
- "Applied Data Science with Python Specialization" by University of Michigan
- Website: https://www.coursera.org

NPTEL (Indian Platform):

- "Introduction to Machine Learning" by IIT Kharagpur
- "Deep Learning" by IIT Madras
- "Data Science for Engineers" by IIT Madras
- Website: https://nptel.ac.in

PRACTICAL LIST:

Session 1: Python Environment Setup & Basic Operations	**Session 7: Clustering Applications** **1. K-means clustering for flight pattern analysis**

1. Installation of ML libraries (scikit-learn, tensorflow, pandas, numpy) 2. Loading and exploring flight dataset (CSV format) 3. Basic statistics and visualization of flight parameters 4. Handling missing values in sensor data	2. Hierarchical clustering for route segmentation 3. Determining optimal number of clusters 4. Visualization of clustered flight data
Session 2: Data Cleaning & Feature Engineering 1. Outlier detection and removal in flight data 2. Feature scaling and normalization techniques 3. Creating new features from raw flight data 4. Time-series feature extraction	Session 8: Anomaly Detection 1. Isolation forest for fault detection 2. One-class SVM for anomaly detection 3. Applications in predictive maintenance 4. Evaluation of anomaly detection systems
Session 3: Exploratory Data Analysis 1. Correlation analysis of aircraft performance parameters 2. Visualization of flight phases using matplotlib/seaborn 3. Statistical analysis of different flight regimes 4. Dimensionality reduction visualization using PCA	Session 9: Dimensionality Reduction 1. Principal Component Analysis (PCA) implementation 2. t-SNE for high-dimensional data visualization 3. Feature selection techniques 4. Applications in flight data compression
Session 4: Regression for Performance Prediction 1. Linear regression for fuel consumption prediction 2. Polynomial regression for nonlinear relationships 3. Model evaluation using RMSE, MAE, R^2 4. Cross-validation implementation	Session 10: Neural Networks with Keras/TensorFlow 1. Building and training basic neural network 2. Hyperparameter tuning for neural networks 3. Implementation of different activation functions 4. Monitoring training with callbacks
Session 5: Classification for Flight Analysis 1. Logistic regression for flight phase classification 2. Decision trees for aircraft system status classification 3. k-NN for pattern recognition in flight data 4. Model evaluation using confusion matrix and metrics	Session 11: Specialized Neural Networks 1. CNN for runway image classification 2. LSTM for flight trajectory prediction 3. Transfer learning for aerospace applications 4. Model deployment considerations
Session 6: Advanced Supervised Learning 1. Random forest for ensemble prediction 2. Gradient boosting for improved accuracy 3. Hyperparameter tuning using grid search 4. Feature importance analysis	Session 12: Integrated Mini-Project Choose one of the following: 1. Aircraft Performance Prediction System: Predict multiple performance parameters 2. Flight Phase Classification System: Real-time flight phase detection 3. Anomaly Detection System: Identify abnormal flight patterns 4. Predictive Maintenance System: Component failure prediction

SEMESTER-IV

SUBJECT CODE: BTAE401

SUBJECT NAME: AERODYNAMICS-I

Course Objectives:

- To understand fundamental principles of aerodynamics and their application to aircraft design
- To analyze incompressible flow over air foils and wings using potential flow theory
- To study boundary layer theory and its implications for drag prediction and flow separation
- To develop skills in aerodynamic analysis and performance prediction of aircraft
- To prepare students for advanced courses in high-speed aerodynamics and computational fluid dynamics

Course Outcomes: At the end of the course students shall be able to

CO1	Apply conservation equations to analyze incompressible flow problems
CO2	Analyze airfoil and wing aerodynamics using potential flow theory
C03	Evaluate boundary layer characteristics and predict flow separation
C04	Design and analyze basic aerodynamic configurations using experimental and computational methods

Unit	Content	Credit	Weightage
I	**FUNDAMENTALS & GOVERNING EQUATIONS** **Review of Fluid Mechanics Concepts**: Continuum hypothesis, fluid properties, viscosity Flow visualization techniques Classification of flows (steady/unsteady, laminar/turbulent, compressible/incompressible) **Governing Equations**: Continuity equation (conservation of mass) Momentum equations (Navier-Stokes equations) Energy equation **Inviscid Flow Approximations**: Euler equations **Bernoulli's Equation**: Derivation, applications, limitations **Circulation and Vorticity**: Definition and physical significance Kelvin's circulation theorem Vortex theorems of Helmholtz **Stream Function and Velocity Potential**: Definitions and relationships Laplace equation for potential flow Elementary flows (uniform, source, sink, vortex, doublet) **Flow Similarity and Dimensionless Numbers**: Reynolds number, Mach number Strouhal number, Froude number	1	25%
II	**AIRFOIL THEORY & CHARACTERISTICS** **Air foil Terminology**:	1	25%

	Chord line, mean camber line, thickness distribution Leading edge radius, trailing edge angle NACA air foil series (4-digit, 5-digit, 6-series) **Air foil Aerodynamic Characteristics**: Lift, drag, and moment coefficients Pressure coefficient distribution Center of pressure and aerodynamic center **Thin Air foil Theory**: Small disturbance approximations Symmetric air foil analysis Cambered air foil analysis Determination of lift slope and moment coefficients **Vortex Panel Methods**: Basic principles Numerical implementation (introduction) **Airfoil Experimental Data**: Use of airfoil data charts Effect of Reynolds number on airfoil characteristics Stall characteristics and maximum lift coefficient **Airfoil Selection Criteria**: For different aircraft applications		
III	**FINITE WING THEORY** **Wing Geometry**: Aspect ratio, taper ratio, sweep angle, twist Mean aerodynamic chord Wing planform shapes **Downwash and Induced Drag**: Physical explanation of downwash Induced drag derivation Trefftz plane analysis **Prandtl's Lifting Line Theory**: Basic assumptions and derivations Elliptical lift distribution General lift distributions Effect of aspect ratio on lift and drag **Monoplane Equation**: Fourier series solution Numerical solution methods **Wing Aerodynamic Characteristics**: Lift curve slope for finite wings Oswald efficiency factor Drag polar for complete aircraft **High-Lift Devices**: Flaps and slats Effect on lift and drag **Vortex Lattice Method**: Basic principles and applications	1	25%
IV	**BOUNDARY LAYER THEORY & DRAG PREDICTION** **Boundary Layer Concept**: Historical development	1	25%

	Physical description Boundary layer thickness definitions (δ, δ*, θ) **Laminar Boundary Layer**: Blasius solution for flat plate Similarity solutions Momentum integral equation **Turbulent Boundary Layer**: Characteristics and structure Velocity profiles (1/7th power law) Turbulence modeling concepts **Boundary Layer Separation**: Physical mechanism Prediction methods Control techniques (vortex generators, boundary layer suction) **Drag Prediction**: Skin friction drag calculation Form drag estimation Interference drag Drag reduction techniques **Flow Transition**: Transition prediction Effect of surface roughness Reynolds number effects **Aerodynamic Performance Prediction**: Complete aircraft drag polar Performance estimation methods Range and endurance equations		

Textbooks:

- "Fundamentals of Aerodynamics" by John D. Anderson Jr. *McGraw-Hill Education, 7th Edition*
- "Introduction to Flight" by John D. Anderson Jr. *McGraw-Hill Education, 9th Edition*
- "Aerodynamics for Engineering Students" by E.L. Houghton, P.W. Carpenter, Steven H. Collicott, and Daniel T. Valentine *Butterworth-Heinemann, 7th Edition*

Reference books:

- "Theory of Wing Sections" by Ira H. Abbott and Albert E. von Doenhoff *Dover Publications*
- "Low-Speed Aerodynamics" by Joseph Katz and Allen Plotkin *Cambridge University Press, 2nd Edition*
- "Boundary-Layer Theory" by Hermann Schlichting and Klaus Gersten *Springer, 9th Edition*
- "Aerodynamics of the Airplane" by Clark B. Millikan *Krieger Publishing Company*
- "Flight Vehicle Aerodynamics" by Mark Drela *MIT Press*

Online Platforms:

NPTEL (National Programme on Technology Enhanced Learning):

- "Aerodynamics" by IIT Kanpur
- "Fluid Mechanics" by IIT Bombay
- "Aircraft Performance and Stability" by IIT Kharagpur
- "Computational Fluid Dynamics" by IIT Bombay

PRACTICAL LIST:

Session 1: Flow Visualization Techniques 1. Smoke tunnel visualization of flow over different shapes 2. Tuft grid visualization of surface flow patterns 3. Oil flow visualization for boundary layer studies 4. Water tunnel visualization using dye injection	**Session 7: Finite Wing Characteristics** 1. Testing of wings with different aspect ratios 2. Measurement of induced drag 3. Effect of taper ratio on spanwise lift distribution 4. Determination of Oswald efficiency factor
Session 2: Pressure Measurement Techniques 1. Calibration of pressure transducers 2. Pressure distribution measurement using multi-tube manometer 3. Pitot-static tube calibration and velocity measurement 4. Surface pressure tap installation and measurement	**Session 8: High-Lift Device Testing** 1. Testing of plain flaps 2. Testing of slotted flaps 3. Effect of flap deflection on lift and drag 4. Optimal flap settings for takeoff and landing
Session 3: Velocity Field Measurement 1. Hot-wire anemometry basic principles 2. Laser Doppler Velocimetry (LDV) demonstration 3. Particle Image Velocimetry (PIV) system overview 4. Simple velocity measurement using pitot tube	**Session 9: Complete Aircraft Model Testing** 1. Testing of complete aircraft model in wind tunnel 2. Measurement of complete aircraft drag polar 3. Effect of configuration changes (gear, flaps) 4. Determination of maximum lift-to-drag ratio
Session 4: Air foil Pressure Distribution 1. Mounting and alignment of airfoil in wind tunnel 2. Pressure distribution measurement at various angles of attack 3. Calculation of lift coefficient from pressure data 4. Comparison with theoretical predictions	**Session 10: Boundary Layer Measurement** 1. Measurement of boundary layer thickness on flat plate 2. Determination of displacement and momentum thickness 3. Observation of laminar to turbulent transition 4. Effect of surface roughness on boundary layer
Session 5: Air foil Force Measurement 1. Use of force balance for lift and drag measurement 2. Determination of lift curve slope 3. Measurement of stall angle and maximum lift coefficient 4. Effect of Reynolds number on air foil characteristics	**Session 11: Drag Measurement & Reduction** 1. Drag measurement of bluff bodies 2. Effect of streamlining on drag reduction 3. Testing of drag reduction devices 4. Interference drag studies
Session 6: Computational Air foil Analysis 1. Introduction to XFOIL software 2. Analysis of NACA air foil series 3. Comparison of computational and experimental results 4. Air foil optimization for specific requirements	1. **Air foil Design and Testing**: Design, analyze, and test a new air foil 2. **Wing Performance Optimization**: Optimize wing parameters for specific mission 3. **Aircraft Configuration Analysis**: Complete analysis of specific aircraft configuration 4. **Drag Reduction Study**: Systematic study of drag reduction techniques

SUBJECT CODE: BTAE402

SUBJECT NAME: STRENGTH OF MATERIALS

Course Objectives:

- To understand stress, strain, and deformation in structural elements under various loading conditions
- To analyze and design beams, shafts, and columns for strength and stability requirements
- To study complex stress states and apply failure theories to aerospace components
- To develop experimental skills in material testing and structural analysis
- To prepare students for advanced courses in aircraft structures and finite element analysis

Course Outcomes: At the end of the course students shall be able to

CO1	Analyze stresses and deformations in axially loaded members and pressure vessels
CO2	Determine shear forces, bending moments, and stresses in beams under various loading conditions
C03	Evaluate torsional behavior and buckling stability of structural components
C04	Apply failure theories and analyze complex stress states in aerospace structures

Unit	Content	Credit	Weightage

I	• **STRESS, STRAIN & MATERIAL BEHAVIOR**
	• **Introduction to Strength of Materials**:
	  ○ Historical perspective and importance in aerospace engineering
	  ○ Types of loads: axial, bending, torsion, shear
	• **Stress Analysis**:
	  ○ Normal stress, shear stress, bearing stress
	  ○ Stress transformation equations
	  ○ Principal stresses and maximum shear stress
	• **Strain Analysis**:
	  ○ Normal strain, shear strain
	  ○ Strain transformation equations
	  ○ Principal strains
	• **Mechanical Properties**:
	  ○ Stress-strain diagrams for ductile and brittle materials
	  ○ Elastic constants: Young's modulus, shear modulus, bulk modulus, Poisson's ratio
	  ○ Relationships between elastic constants
	• **Axially Loaded Members**:
	  ○ Deformation of prismatic and non-prismatic bars
	  ○ Statically determinate and indeterminate problems
	  ○ Thermal stresses and strains
		1	25%

	• **Thin-Walled Pressure Vessels**: ○ Cylindrical and spherical vessels ○ Hoop and longitudinal stresses • **Aerospace Applications**: ○ Aircraft fuselage pressurization stresses ○ Rocket motor casing analysis ○ Landing gear strut design		
II	• **BENDING OF BEAMS** • **Beam Types and Supports**: ○ Simply supported, cantilever, overhanging, continuous beams ○ Types of supports: fixed, pinned, roller • **Shear Force and Bending Moment**: ○ Sign conventions ○ Relationships between load, shear force, and bending moment ○ SFD and BMD for various loading conditions • **Bending Stresses**: ○ Theory of pure bending ○ Flexure formula derivation ○ Section modulus ○ Bending stresses in symmetric and unsymmetric sections • **Shear Stresses in Beams**: ○ Shear stress formula derivation ○ Shear stress distribution in rectangular, circular, and I-sections ○ Shear flow in built-up sections • **Deflection of Beams**: ○ Differential equation of elastic curve ○ Double integration method ○ Macaulay's method ○ Moment-area method • **Aerospace Applications**: ○ Aircraft wing spar analysis ○ Fuselage frame bending ○ Control surface hinge moments	1	25%
III	• **TORSION & BUCKLING** • **Torsion of Circular Shafts**: ○ Theory of pure torsion ○ Torsion formula derivation ○ Angle of twist calculation ○ Power transmission in shafts • **Non-Circular Sections**: ○ Torsion of rectangular sections ○ Thin-walled open and closed sections	1	25%

	○ Torsion constant calculations • **Combined Loading**: ○ Bending and torsion ○ Axial load and bending ○ Combined stress calculations • **Springs**: ○ Helical springs under axial load ○ Spring rate and deflection ○ Shear stress in springs • **Column Buckling**: ○ Euler's buckling theory for columns ○ Effective length concepts ○ Critical buckling load for various end conditions ○ Slenderness ratio • **Empirical Column Formulas**: ○ Rankine-Gordon formula ○ Johnson's parabolic formula ○ AISC column formulas • **Aerospace Applications**: ○ Aircraft engine shaft design ○ Landing gear torsion analysis ○ Aircraft structural column design ○ Control cable tension analysis		
IV	○ **COMPLEX STRESSES & FAILURE THEORIES** • **Stress Transformation**: ○ Plane stress transformation equations ○ Mohr's circle for stress ○ Principal stresses and maximum shear stress • **Strain Transformation**: ○ Plane strain transformation ○ Mohr's circle for strain ○ Strain rosettes and calculations • **Theories of Failure**: ○ Maximum principal stress theory (Rankine) ○ Maximum shear stress theory (Tresca) ○ Maximum distortion energy theory (von Mises) ○ Maximum principal strain theory (Saint-Venant) ○ Application to ductile and brittle materials • **Stress Concentration**: ○ Causes and effects ○ Stress concentration factors ○ Methods to reduce stress concentration • **Fatigue Analysis**: ○ Introduction to fatigue failure ○ S-N curves	1	25%

	○ Endurance limit ○ Factors affecting fatigue strength • **Impact Loading**: ○ Energy methods for impact problems ○ Stress and deflection under impact loading • **Aerospace Applications**: ○ Aircraft component failure analysis ○ Fatigue life estimation ○ Stress concentration in aircraft structures ○ Impact analysis for crashworthiness		

Textbooks:

- "Mechanics of Materials" by R.C. Hibbeler *Pearson, 11th Edition*
- "Strength of Materials" by S. Timoshenko and D.H. Young *McGraw-Hill*
- "Advanced Strength and Applied Elasticity" by A.C. Ugural and S.K. Fenster *Pearson, 5th Edition*

Reference books:

- "Mechanics of Materials" by James M. Gere and Barry J. Goodno *Cengage Learning, 9th Edition*
- "Strength of Materials" by B.C. Punmia, Ashok Kumar Jain, and Arun Kumar Jain *Laxmi Publications*
- "Engineering Mechanics of Materials" by B.B. Muvdi and J.W. McNabb *Springer*
- "Roark's Formulas for Stress and Strain" by Warren C. Young and Richard G. Budynas *McGraw-Hill, 8th Edition*
- "Fundamentals of Machine Component Design" by Robert C. Juvinall and Kurt M. Marshek *Wiley, 6th Edition*

Online Platforms:

NPTEL (National Programme on Technology Enhanced Learning):

- "Strength of Materials" by IIT Madras
- "Advanced Strength of Materials" by IIT Roorkee
- "Mechanics of Solids" by IIT Kharagpur
- "Structural Analysis" by IIT Bombay

PRACTICAL LIST:

Session 1: Tensile Testing of Aerospace Materials 1. Preparation of tensile test specimens (aluminium alloy, steel) 2. Conducting tensile test on Universal Testing Machine 3. Determination of: Young's modulus, yield strength, ultimate strength, percentage elongation 4. Plotting stress-strain diagrams and comparing material behaviors	**Session 7: Torsion Testing** 1. Torsion test of circular shafts 2. Measurement of angle of twist vs applied torque 3. Determination of shear modulus 4. Comparison of solid vs hollow shafts
Session 2: Compression Testing 1. Compression test of ductile and brittle materials 2. Determination of compressive strength 3. Study of buckling in slender columns	**Session 8: Spring Testing** 1. Compression test of helical springs 2. Determination of spring constant 3. Shear stress calculation in spring wire

4. Comparison of tensile vs compressive behavior	4. Spring deflection under various loads
Session 3: Hardness Testing & Impact Testing 1. Brinell and Rockwell hardness tests 2. Calculation of hardness numbers 3. Charpy impact test for toughness determination 4. Effect of temperature on impact strength	**Session 9: Combined Loading Analysis** 1. Beam under combined bending and torsion 2. Shaft under combined torsion and axial load 3. Experimental stress analysis using strain rosettes 4. Verification using superposition principle
Session 4: Beam Bending Test 1. Three-point bending test of simply supported beam 2. Four-point bending test for pure bending region 3. Measurement of bending stresses using strain gauges 4. Comparison with theoretical bending stress calculations	**Session 10: Column Buckling Test** 1. Euler buckling test of slender columns 2. Effect of end conditions on buckling load 3. Determination of effective length factors 4. Comparison with theoretical predictions
Session 5: Shear Force & Bending Moment Verification 1. Experimental determination of SFD and BMD 2. Comparison with analytical calculations 3. Effect of different loading conditions 4. Study of support reactions	**Session 11: Thin-Walled Pressure Vessel** 1. Strain measurement on pressure vessel 2. Determination of hoop and longitudinal stresses 3. Comparison with theoretical calculations 4. Study of end effects
Session 6: Beam Deflection Measurements 1. Measurement of beam deflections using dial gauges/LVDTs 2. Cantilever beam deflection under point load and UDL 3. Simply supported beam deflection verification 4. Comparison with theoretical deflection calculations	**Session 12: Integrated Project Choose one of the following:** 1. **Aircraft Component Analysis**: Stress analysis of a specific aircraft component 2. **Material Selection Study**: Comparative study of different aerospace materials 3. **Failure Analysis Project**: Analysis of failed component using strength principles 4. **Design Verification**: Experimental verification of designed structural element

SUBJECT CODE: BTAE403

SUBJECT NAME: AIRCRAFT PROPULSION-I

Course Objectives:

- To understand fundamental principles of aircraft propulsion systems and their working mechanisms
- To analyze thermodynamics and aerodynamics of air-breathing engines
- To study performance characteristics of different propulsion systems for various flight regimes
- To develop experimental skills in propulsion system testing and analysis
- To prepare students for advanced courses in gas turbine technology and rocket propulsion

Course Outcomes: At the end of the course students shall be able to

CO1	Analyze thermodynamic cycles and performance parameters of aircraft propulsion systems
CO2	Evaluate components and working principles of different types

	of aircraft engines
C03	Calculate performance characteristics and conduct experimental analysis of propulsion systems
C04	Design and analyze propulsion system components and conduct performance optimization studies

Unit	Content	Credit	Weightage

I	**FUNDAMENTALS OF PROPULSION & THERMODYNAMIC CYCLES**
	
	• **Introduction to Aircraft Propulsion**:
	  ◦ Historical development of aircraft propulsion
	  ◦ Types of propulsion systems: air-breathing vs non-air-breathing
	  ◦ Thrust generation principles
	• **Review of Thermodynamics**:
	  ◦ Laws of thermodynamics
	  ◦ Gas properties and equations of state
	  ◦ Isentropic flow relations
	• **Standard Atmosphere**:
	  ◦ International Standard Atmosphere (ISA) model
	  ◦ Variation of pressure, temperature, density with altitude
	• **Propulsion Performance Parameters**:
	  ◦ Thrust, specific thrust, thrust specific fuel consumption (TSFC)
	  ◦ Propulsive efficiency, thermal efficiency, overall efficiency
	  ◦ Specific impulse
	• **Thermodynamic Cycles**:
	  ◦ Otto cycle (piston engines)
	  ◦ Brayton cycle (gas turbine engines)
	  ◦ Ideal vs actual cycles
	  ◦ Cycle efficiency calculations
	• **Aircraft Engine Classification**:
	  ◦ Reciprocating engines
	  ◦ Turbojet engines
	  ◦ Turbofan engines
	  ◦ Turboprop engines
	  ◦ Turboshaft engines
	• **Aerothermodynamics of Ducts**:
	  ◦ Diffusers and nozzles
	  ◦ Choking conditions
	  ◦ Area-Mach number relationship
		1	25%

II	**COMPRESSORS & COMBUSTION SYSTEMS** • **Compressor Fundamentals**:	1	25%

	○ Purpose and classification (axial vs centrifugal) ○ Compression processes ○ Isentropic efficiency of compressors • **Centrifugal Compressors**: ○ Working principle and components ○ Velocity triangles ○ Performance characteristics ○ Slip factor and pressure coefficient • **Axial Flow Compressors**: ○ Construction and working principle ○ Stage velocity triangles ○ Degree of reaction ○ Compressor maps and stall characteristics • **Compressor Performance**: ○ Pressure ratio and temperature rise ○ Work input calculations ○ Surge and stall phenomena ○ Compressor blade design considerations • **Combustion Systems**: ○ Combustion fundamentals ○ Combustion chamber types (can, annular, can-annular) ○ Combustion efficiency and completeness ○ Emission formation and control • **Combustion Chamber Design**: ○ Air-fuel mixing ○ Flame stabilization ○ Cooling techniques ○ Liner materials and coatings • **Fuel Injection Systems**: ○ Fuel atomization ○ Spray characteristics ○ Fuel control systems		
III	**TURBINES & NOZZLES** • **Turbine Fundamentals**: ○ Energy extraction principles ○ Classification (impulse vs reaction) ○ Turbine efficiency definitions • **Axial Flow Turbines**: ○ Construction and components ○ Velocity triangles for turbine stages ○ Degree of reaction for turbines ○ Blade cooling techniques • **Radial Turbines**: ○ Construction and working principle ○ Applications in small engines ○ Performance characteristics	1	25%

	• **Turbine Performance**: o Work output calculations o Efficiency parameters o Turbine matching with compressor o Turbine blade materials and cooling • **Nozzles**: o Types of nozzles (convergent, convergent-divergent) o Nozzle flow analysis o Choking conditions o Thrust coefficient and nozzle efficiency • **Variable Area Nozzles**: o Supersonic engine applications o Afterburner integration o Thrust vectoring concepts • **Jet Noise**: o Sources of jet noise o Noise reduction techniques o Acoustic liners		
IV	**ENGINE PERFORMANCE & INTEGRATION** • **Engine Performance Analysis**: o On-design and off-design performance o Engine matching and operating lines o Engine performance maps • **Turbojet Engine Analysis**: o Component matching o Performance at different altitudes and speeds o Fuel flow characteristics • **Turbofan Engine Analysis**: o Bypass ratio effects o Fan and core performance o High bypass vs low bypass engines • **Turboprop Engine Analysis**: o Propeller efficiency o Power turbine characteristics o Shaft power calculations • **Engine Installation**: o Nacelle design o Inlet design considerations o Thrust reverser systems • **Engine Starting Systems**: o Starting sequence o Starter types (electric, pneumatic, hydraulic) o Ignition systems • **Engine Control Systems**: o Fuel control systems	1	25%

	○ Electronic engine control (EEC) ○ Full Authority Digital Engine Control (FADEC) • **Auxiliary Systems**: ○ Lubrication systems ○ Cooling systems ○ Power extraction systems • **Engine Testing & Certification**: ○ Ground testing procedures ○ Flight testing ○ Certification requirements		

Textbooks:

- "Aircraft Propulsion" by Saeed Farokhi *Wiley, 2nd Edition*
- "Gas Turbine Theory" by H.I.H. Saravanamuttoo, G.F.C. Rogers, and H. Cohen *Pearson, 7th Edition*
- "Elements of Gas Turbine Propulsion" by Jack D. Mattingly *AIAA Education Series*

Reference books:

- "Mechanics and Thermodynamics of Propulsion" by Philip G. Hill and Carl R. Peterson *Pearson, 2nd Edition*
- "Aircraft Engine Design" by Jack D. Mattingly, William H. Heiser, and David T. Pratt *AIAA Education Series, 3rd Edition*
- "Jet Propulsion: A Simple Guide to the Aerodynamic and Thermodynamic Design and Performance of Jet Engines" by Nicholas Cumpsty and Andrew Heyes *Cambridge University Press, 3rd Edition*
- "The Jet Engine" by Rolls-Royce plc *Rolls-Royce Technical Publications*
- "Fundamentals of Jet Propulsion with Applications" by Ronald D. Flack *Cambridge University Press*

Online Platforms:

NPTEL (National Programme on Technology Enhanced Learning):

- "Aircraft Propulsion" by IIT Madras
- "Gas Turbines and Jet Propulsion" by IIT Kharagpur
- "Propulsion" by IIT Bombay
- "Rocket Propulsion" by IIT Kanpur

PRACTICAL LIST:

Session 1: Propulsion Performance Calculations 1. Calculation of thrust using momentum theory 2. Specific fuel consumption calculations 3. Efficiency calculations (thermal, propulsive, overall) 4. Analysis of engine performance at different altitudes	**Session 7: Small Gas Turbine Engine Testing** 1. Startup procedure for small gas turbine 2. Thrust measurement at different RPM 3. Fuel consumption measurement 4. Performance curve generation
Session 2: Compressor Performance Analysis 1. Study of centrifugal compressor components 2. Pressure ratio measurement across compressor 3. Calculation of compressor efficiency	**Session 8: Engine Vibration Analysis** 1. Vibration measurement on engine components 2. Frequency spectrum analysis

4. Performance mapping using experimental data	3. Balancing demonstration 4. Vibration damping techniques
Session 3: Turbine Performance Analysis 1. Study of axial flow turbine components 2. Temperature drop measurement across turbine 3. Calculation of turbine efficiency 4. Work output calculations	**Session 9: Thermal Analysis** 1. Temperature measurement on engine components 2. Heat transfer studies 3. Cooling effectiveness evaluation 4. Thermal stress analysis
Session 4: Combustion Chamber Testing 1. Combustion efficiency measurement 2. Flame temperature measurement 3. Emission analysis (CO, CO_2, NOx measurement) 4. Combustion stability studies	**Session 10: Propeller Performance** 1. Propeller thrust measurement 2. Propeller efficiency calculation 3. Pitch angle effects on performance 4. Comparison with theoretical predictions
Session 5: Nozzle Performance Testing 1. Thrust measurement from different nozzle configurations 2. Flow visualization in nozzles 3. Choking condition verification 4. Nozzle efficiency calculations	**Session 11: Jet Engine Noise Measurement** 1. Sound level measurement 2. Frequency analysis of jet noise 3. Noise reduction techniques demonstration 4. Acoustic liner effectiveness study
Session 6: Engine Component Matching 1. Compressor-turbine matching exercise 2. Fuel flow measurement and control 3. Engine speed governing 4. Performance data recording and analysis	1. **Engine Performance Optimization**: Optimization of engine parameters for specific mission 2. **Component Redesign Project**: Redesign of engine component for improved performance 3. **Engine Cycle Analysis**: Complete thermodynamic analysis of engine cycle 4. **Engine Testing Program**: Design and execution of engine test program

SUBJECT CODE: BTAE404

SUBJECT NAME: FLIGHT MECHANICS

Course Objectives:

- To understand fundamental principles of aircraft flight mechanics and stability
- To analyze aircraft performance parameters under various flight conditions
- To study aircraft stability, control, and handling qualities
- To develop skills in flight data analysis and performance prediction
- To prepare students for advanced courses in flight dynamics and control systems

Course Outcomes: At the end of the course students shall be able to

CO1	Analyze aircraft performance parameters and flight envelope for different configurations
CO2	Evaluate aircraft stability characteristics and control effectiveness
C03	Conduct flight performance calculations and experimental analysis

	using flight data
C04	Design flight test procedures and analyze aircraft handling qualities

PRACTICAL LIST:

Session 1: Aircraft Performance Calculations 1. Calculation of aircraft weight and balance 2. Determination of center of gravity position 3. Weight and balance envelope construction 4. Effect of loading on aircraft performance **Session 2: Takeoff and Landing Performance** 1. Calculation of takeoff distance (ground roll, rotation, climb segment) 2. Landing distance calculation (approach, flare, ground roll) 3. Effect of runway conditions, wind, and temperature 4. Performance charts interpretation and application	**Session 7: Flight Simulation Setup** 1. Introduction to flight simulation software 2. Aircraft model configuration and validation 3. Flight instrument panel familiarization 4. Basic flight maneuvers practice **Session 8: Flight Data Recording and Analysis** 1. Setting up flight data recording 2. Data extraction and processing 3. Flight parameter analysis (airspeed, altitude, attitude) 4. Performance parameter calculation from flight data
Session 3: Climb and Cruise Performance 1. Rate of climb calculations 2. Time to climb estimation 3. Best climb speed determination 4. Cruise performance analysis (range, endurance calculations)	**Session 9: Flight Maneuver Analysis** 1. Standard rate turns analysis 2. Stall characteristics study 3. Spiral dive analysis 4. Phugoid and short period mode identification
Session 4: Longitudinal Stability Analysis 1. Determination of neutral point and static margin 2. Calculation of stick-fixed and stick-free stability 3. Effect of center of gravity position on stability 4. Longitudinal stability derivatives calculation	**Session 10: Flight Test Planning** 1. Design of flight test cards 2. Risk assessment for flight testing 3. Instrumentation requirements planning 4. Data acquisition system setup
Session 5: Lateral-Directional Stability 1. Dihedral effect analysis 2. Weathercock stability evaluation 3. Spiral and Dutch roll mode analysis 4. Lateral stability derivatives calculation	**Session 11: Virtual Flight Testing** 1. Conducting virtual flight tests 2. Performance testing (takeoff, climb, cruise) 3. Stability testing (static and dynamic) 4. Control response testing
Session 6: Control Effectiveness 1. Calculation of control surface effectiveness 2. Hinge moment analysis 3. Control forces prediction 4. Trim analysis for different flight conditions	**Session 12: Integrated Project** **Choose one of the following:** 1. **Aircraft Performance Evaluation**: Complete performance analysis of specific aircraft 2. **Stability Augmentation Design**: Design of stability augmentation system 3. **Flight Test Program Development**: Complete flight test program for certification 4. **Aircraft Handling Qualities Analysis**: Detailed analysis of aircraft handling characteristics

SEMESTER-V

SUBJECT CODE: BTAE501

SUBJECT NAME: AERODYNAMICS-II

- Course Objectives:
- To understand compressible flow phenomena and shock wave dynamics in aerospace applications
- To analyze high-speed aerodynamic flows over airfoils, wings, and bodies
- To study supersonic and hypersonic flow characteristics and their impact on aircraft design
- To develop computational and experimental skills for high-speed aerodynamic analysis
- To prepare students for advanced courses in computational fluid dynamics and high-speed aerodynamics

Course Outcomes: At the end of the course students shall be able to

CO1	Analyze compressible flow phenomena and calculate properties across normal and oblique shock waves
CO2	Evaluate supersonic airfoil and wing characteristics using linearized theory and method of characteristics
C03	Conduct experimental and computational analysis of high-speed aerodynamic flows
C04	Design and analyze aerodynamic configurations for high-speed flight applications

Unit	Content	Credit	Weightage

I	**COMPRESSIBLE FLOW FUNDAMENTALS**
	
	• **Review of Thermodynamics**:
	  ○ Perfect gas relations
	  ○ Isentropic flow equations
	  ○ Stagnation properties
	• **One-Dimensional Isentropic Flow**:
	  ○ Area-Mach number relation
	  ○ Choking conditions
	  ○ Convergent and convergent-divergent nozzles
	  ○ Nozzle flow regimes (subsonic, sonic, supersonic)
	• **Normal Shock Waves**:
	  ○ Physical mechanism and formation
	  ○ Rankine-Hugoniot relations
	  ○ Property ratios across normal shocks
	  ○ Mach number relations
	• **Flow Through Nozzles and Diffusers**:
	  ○ Nozzle performance
	  ○ Overexpanded and underexpanded nozzles
	  ○ Supersonic diffuser operation
	• **Applications to Propulsion**:
	  ○ Jet engine intake design
	  ○ Rocket nozzle design
		1	25%

	• **Numerical Methods**:
	  ○ Quasi-one-dimensional flow analysis
	  ○ Method of characteristics for 1D flow		

II	**OBLIQUE SHOCKS & EXPANSION WAVES**
	
	• **Oblique Shock Waves**:
	  ○ Physical mechanism
	  ○ θ-β-M relation
	  ○ Shock polar diagrams
	  ○ Maximum deflection angle
	• **Prandtl-Meyer Expansion Waves**:
	  ○ Prandtl-Meyer function
	  ○ Expansion fan characteristics
	  ○ Property changes across expansion waves
	• **Shock-Expansion Theory**:
	  ○ Application to supersonic airfoils
	  ○ Diamond and double-wedge airfoils
	  ○ Lift and drag calculations
	• **Shock Interactions**:
	  ○ Shock-shock interactions
	  ○ Shock-boundary layer interactions
	  ○ Reflected shocks
	• **Supersonic Flow Over Wedges and Cones**:
	  ○ Two-dimensional vs axisymmetric flows
	  ○ Cone shock angles
	  ○ Taylor-Maccoll equations
	• **Applications**:
	  ○ Supersonic inlet design
	  ○ Supersonic airfoil design
	  ○ High-speed vehicle design
		1	25%

III	**LINEARIZED SUPERSONIC FLOW & METHOD OF**
	
	• **Linearized Supersonic Flow Theory**:
	  ○ Small perturbation theory
	  ○ Prandtl-Glauert equation for supersonic flow
	  ○ Pressure coefficient relations
	• **Supersonic Airfoil Theory**:
	  ○ Ackeret's theory
	  ○ Wave drag of airfoils
	  ○ Lift and moment coefficients
	  ○ Supercritical airfoils
	• **Method of Characteristics**:
	  ○ Characteristics in supersonic flow
	  ○ Compatibility equations
	  ○ Numerical implementation
	  ○ Nozzle design using MOC
	• **Supersonic Wing Theory**:
		1	25%

	○ Supersonic wing planforms ○ Lift distribution on finite wings ○ Drag due to lift ○ Aspect ratio effects • **Three-Dimensional Supersonic Flow**: ○ Flow over cones at angle of attack ○ Slender body theory ○ Wing-body interference • **Applications**: ○ Supersonic aircraft design ○ High-speed missile aerodynamics ○ Launch vehicle aerodynamics		
IV	**HYPERSONIC AERODYNAMICS & SPECIAL TOPICS** • **Hypersonic Flow Characteristics**: ○ Definition and regimes (M > 5) ○ Thin shock layers ○ Entropy layers ○ Viscous interaction effects • **Hypersonic Similarity**: ○ Hypersonic similarity parameter ○ Mach number independence principle • **Newtonian Flow Theory**: ○ Newtonian impact theory ○ Modified Newtonian theory ○ Pressure coefficient predictions • **High-Temperature Effects**: ○ Real gas effects ○ Vibrational excitation ○ Dissociation and ionization ○ Equilibrium and non-equilibrium flow • **Aerodynamic Heating**: ○ Heat transfer at high speeds ○ Thermal protection systems ○ Material requirements for hypersonic flight • **Special Topics**: ○ Transonic flow characteristics ○ Area ruling ○ Supercritical airfoils ○ Drag divergence • **Applications**: ○ Re-entry vehicle aerodynamics ○ Hypersonic vehicle design ○ Space shuttle aerodynamics ○ SCRAMJET engine aerodynamics	1	25%

Textbooks:

- "Fundamentals of Aerodynamics" by John D. Anderson Jr. *McGraw-Hill Education, 7th Edition*
- "Modern Compressible Flow: With Historical Perspective" by John D. Anderson Jr.

McGraw-Hill Education, 4th Edition

- "Aerodynamics for Engineering Students" by E.L. Houghton, P.W. Carpenter, Steven H. Collicott, and Daniel T. Valentine *Butterworth-Heinemann, 7th Edition*

Reference books:

- "Elements of Gasdynamics" by H.W. Liepmann and A. Roshko *Dover Publications*
- "Foundations of Aerodynamics: Bases of Aerodynamic Design" by A.M. Kuethe and C.-Y. Chow *Wiley, 5th Edition*
- "Hypersonic and High-Temperature Gas Dynamics" by John D. Anderson Jr. *AIAA Education Series, 3rd Edition*
- "Supersonic Flow and Shock Waves" by R. Courant and K.O. Friedrichs *Springer*
- "Aerothermodynamics of Aircraft Engine Components" edited by G.C. Oates *AIAA Education Series*

Online Platforms:

NPTEL (National Programme on Technology Enhanced Learning):

- "High Speed Aerodynamics" by IIT Kanpur
- "Compressible Fluid Flow" by IIT Bombay
- "Computational Fluid Dynamics" by IIT Kharagpur
- "Aerodynamics" by IIT Madras
- Website: https://nptel.ac.in

PRACTICAL LIST:

Session 1: Shock Wave Visualization 1. Schlieren system setup and calibration 2. Visualization of normal shocks in nozzles 3. Observation of shock diamonds in under expanded jets 4. Shadowgraph technique demonstration	Session 7: Computational Setup and Validation 1. Geometry creation for supersonic flow analysis 2. Mesh generation for compressible flow 3. Boundary condition specification 4. Solver setup and initialization
Session 2: Nozzle Flow Analysis 1. Pressure distribution measurement in convergent-divergent nozzle 2. Determination of nozzle performance characteristics 3. Choking condition verification 4. Mass flow rate measurements	Session 8: CFD Analysis of Supersonic Flow 1. Simulation of flow over supersonic airfoil 2. Shock wave capturing techniques 3. Comparison with experimental data 4. Error analysis and convergence study
Session 3: Supersonic Flow Over Simple Bodies 1. Visualization of flow over wedges at different angles 2. Shock angle measurement and comparison with theory 3. Pressure distribution on wedge surfaces 4. Drag measurement using force balance	Session 9: Nozzle Flow Simulation 1. CFD analysis of convergent-divergent nozzle 2. Shock position prediction 3. Mass flow rate calculation 4. Performance optimization study
Session 4: Supersonic Airfoil Characteristics 1. Testing of diamond airfoil in supersonic flow 2. Pressure distribution measurement 3. Lift and drag calculation from pressure data	Session 10: High-Speed Flow Instrumentation 1. High-frequency pressure transducer calibration 2. Temperature measurement in high-speed

4. Comparison with shock-expansion theory predictions	flow 3. Heat transfer rate measurement 4. Instrument response time analysis
Session 5: Supersonic Wing Performance 1. Testing of swept and unswept wings 2. Measurement of lift and drag characteristics 3. Effect of sweep angle on wave drag 4. Wing tip vortex visualization	Session 11: Aerodynamic Heating Studies 1. Temperature measurement on heated models 2. Heat flux calculation 3. Thermal boundary layer studies 4. Cooling effectiveness evaluation
Session 6: Boundary Layer-Shock Interaction 1. Visualization of shock-boundary layer interaction 2. Pressure measurement near interaction region 3. Separation bubble observation 4. Effect of surface roughness	Session 12: Integrated Project Choose one of the following: 1. Supersonic Airfoil Design: Design and analysis of supersonic airfoil 2. Nozzle Optimization: Design optimization of supersonic nozzle 3. Shock Wave Control: Study of shock control techniques 4. High-Speed Vehicle Configuration Analysis: Complete analysis of high-speed vehicle

SUBJECT CODE: BTAE502

SUBJECT NAME: AIRCRAFT STRUCTURES-II

Course Objectives:

- To analyze complex aircraft structural systems including stiffened panels, plates, and shells
- To apply energy methods and advanced structural analysis techniques to aircraft components
- To understand fatigue, fracture mechanics, and damage tolerance concepts for aircraft structures
- To develop skills in structural testing, finite element analysis, and experimental stress analysis
- To prepare students for aircraft structural design, certification, and maintenance engineering

Course Outcomes: At the end of the course students shall be able to

CO1	Analyze advanced aircraft structural components using energy methods and plate theory
CO2	Apply fatigue and fracture mechanics principles to aircraft structural life prediction
C03	Conduct experimental and computational analysis of complex aircraft structures
C04	Design and evaluate aircraft structural components considering damage tolerance and certification requirements

Unit	Content	Credit	Weightage
I	**ADVANCED STRUCTURAL ANALYSIS METHODS** • **Energy Methods**:	1	25%

	○ Principle of virtual work ○ Castigliano's theorems ○ Minimum potential energy principle ○ Rayleigh-Ritz method • **Finite Element Method Applications**: ○ Review of FEM fundamentals ○ Beam and frame elements ○ Plate and shell elements ○ Convergence and accuracy considerations • **Structural Dynamics Basics**: ○ Free and forced vibrations ○ Natural frequencies and mode shapes ○ Dynamic response to harmonic and impulsive loads • **Aeroelasticity Introduction**: ○ Divergence and flutter concepts ○ Static and dynamic aeroelasticity ○ Control surface reversal • **Composite Structures Analysis**: ○ Lamina and laminate analysis ○ Failure criteria for composites ○ Stress-strain relationships • **Applications**: ○ Wing box analysis ○ Fuselage frame analysis ○ Control surface stiffness requirements		
II	**PLATES, SHELLS & STIFFENED PANELS** • **Bending of Thin Plates**: ○ Kirchhoff-Love plate theory ○ Governing differential equation ○ Boundary conditions (simply supported, clamped, free) ○ Solutions for rectangular and circular plates • **Buckling of Plates**: ○ Critical buckling loads for various boundary conditions ○ Post-buckling strength ○ Effect of in-plane loading • **Stiffened Panels**: ○ Stringer-stiffened panels ○ Waffle panels ○ Effective width concept ○ Crippling of stiffeners • **Shell Structures**: ○ Membrane theory of shells ○ Bending theory of cylindrical shells ○ Fuselage shell analysis	1	25%

	• **Pressure Vessel Analysis**:
	  ○ Thin-walled pressure vessels
	  ○ Thick-walled cylinders
	  ○ End closure analysis
	• **Applications**:
	  ○ Aircraft skin panels
	  ○ Fuselage shell analysis
	  ○ Wing skin-stringer panels
	  ○ Pressure cabin design		

III	**FATIGUE & FRACTURE MECHANICS**
	• **Fatigue of Materials**:
	  ○ S-N curves and endurance limits
	  ○ Mean stress effects (Goodman, Gerber diagrams)
	  ○ Cumulative damage theories (Miner's rule)
	  ○ Factors affecting fatigue strength
	• **Fracture Mechanics**:
	  ○ Griffith's theory of brittle fracture
	  ○ Stress intensity factor (K)
	  ○ Fracture toughness (K_IC, K_C)
	  ○ Crack tip plastic zone
	• **Fatigue Crack Growth**:
	  ○ Paris' law
	  ○ Crack growth rate determination
	  ○ Life prediction using fracture mechanics
	  ○ Retardation and acceleration effects
	• **Damage Tolerance**:
	  ○ Safe-life vs damage-tolerant design
	  ○ Inspection intervals determination
	  ○ Residual strength analysis
	• **Environmental Effects**:
	  ○ Corrosion fatigue
	  ○ Stress corrosion cracking
	  ○ High-temperature effects
	• **Applications**:
	  ○ Aircraft structural life prediction
	  ○ Inspection program development
	  ○ Repair design considerations
	  ○ Failure investigation methods
		1	25%

IV	**STRUCTURAL DESIGN & CERTIFICATION**
	• **Aircraft Structural Design Philosophy**:
	  ○ Fail-safe design principles
	  ○ Multiple load path structures
	  ○ Structural redundancy
	  ○ Damage arrest features
	• **Loads and Stresses**:
		1	25%

	○ Airworthiness requirements (FAR 25, CS-25) ○ Ultimate and limit loads ○ Factor of safety considerations • **Structural Testing**: ○ Static strength testing ○ Fatigue testing ○ Full-scale testing ○ Instrumentation and data acquisition • **Structural Repairs**: ○ Repair classification ○ Bonded and bolted repairs ○ Composite repairs ○ Temporary and permanent repairs • **Certification Requirements**: ○ Type certification process ○ Compliance demonstration methods ○ Continued airworthiness ○ Aging aircraft programs • **Modern Trends**: ○ Structural health monitoring ○ Digital twin concepts ○ Additive manufacturing for structures ○ Smart structures • **Case Studies**: ○ Aircraft structural failures ○ Successful structural designs ○ Certification challenges		

Textbooks:

- "Aircraft Structures for Engineering Students" by T.H.G. Megson *Elsevier, 7th Edition*
- "Analysis of Aircraft Structures: An Introduction" by Bruce K. Donaldson *Cambridge University Press, 2nd Edition*
- "Airframe Structural Design: Practical Design Information and Data on Aircraft Structures" by Michael C.Y. Niu *Hong Kong Commilit Press, 2nd Edition*

Reference books:

- "Bruhn's Analysis and Design of Flight Vehicle Structures" by E.F. Bruhn *Jacobs Publishing*
- "Fracture Mechanics: Fundamentals and Applications" by T.L. Anderson *CRC Press, 4th Edition*
- "Fatigue of Structures and Materials" by J. Schijve *Springer, 2nd Edition*
- "Composite Materials for Aircraft Structures" by A.A. Baker, S. Dutton, and D. Kelly *AIAA Education Series, 3rd Edition*
- "Finite Element Procedures" by Klaus-Jürgen Bathe *Prentice Hall*

Online Platforms:

NPTEL (National Programme on Technology Enhanced Learning):

- "Advanced Aircraft Structures" by IIT Kharagpur
- "Fracture Mechanics" by IIT Bombay
- "Finite Element Analysis" by IIT Kanpur
- "Fatigue and Fracture" by IIT Madras

- Website: https://nptel.ac.in

PRACTICAL LIST:

Session 1: Energy Methods Application 1. Analysis of redundant frames using Castigliano's theorem 2. Deflection calculation of complex beams using virtual work 3. Stiffness matrix formulation for simple structures 4. Comparison with exact solutions	**Session 7: FEA Model Development** 1. Geometry creation for aircraft structural component 2. Mesh generation and quality assessment 3. Material property assignment 4. Boundary condition application
Session 2: Plate Bending Analysis 1. Experimental study of plate bending under uniform load 2. Deflection measurement using dial gauges/LVDTs 3. Strain measurement on plate surface 4. Comparison with classical plate theory predictions	**Session 8: Static Structural Analysis** 1. Linear static analysis of wing rib 2. Stress and deformation visualization 3. Comparison with analytical solutions 4. Error estimation and convergence study
Session 3: Stiffened Panel Testing 1. Testing of stringer-stiffened aluminum panel 2. Load-deflection characteristics measurement 3. Buckling load determination 4. Post-buckling behavior observation	**Session 9: Dynamic Analysis** 1. Modal analysis of aircraft component 2. Natural frequency determination 3. Mode shape visualization 4. Harmonic response analysis
Session 4: Fatigue Testing 1. Preparation of fatigue test specimens 2. S-N curve determination for aluminum alloy 3. Effect of stress concentration on fatigue life 4. Mean stress effect demonstration	**Session 10: Non-Destructive Testing** 1. Ultrasonic testing for crack detection 2. Dye penetrant inspection 3. Eddy current testing demonstration 4. Thermography for defect detection
Session 5: Fracture Toughness Testing 1. Preparation of fracture mechanics specimens 2. Crack length measurement techniques 3. Determination of stress intensity factor 4. Fracture toughness (K_IC) calculation	**Session 11: Structural Health Monitoring** 1. Strain gauge installation and calibration 2. Acoustic emission monitoring 3. Vibration-based damage detection 4. Data acquisition system setup
Session 6: Fatigue Crack Growth 1. Crack growth rate measurement 2. Paris' law parameter determination 3. Effect of stress ratio on crack growth 4. Life prediction using fracture mechanics	**Session 12: Integrated Project** **Choose one of the following:** 1. **Aircraft Component Redesign**: Redesign of structural component for improved performance 2. **Fatigue Life Prediction**: Complete fatigue analysis of aircraft component 3. **Damage Tolerance Analysis**: Damage tolerance assessment of critical component 4. **Structural Repair Design**: Design of repair scheme for damaged structure

SUBJECT CODE: BTAE503

SUBJECT NAME: AIRCRAFT PROPULSION-II

Course Objectives:

- To analyze advanced gas turbine engine components and their performance characteristics
- To study engine-airframe integration, control systems, and installation effects
- To understand rocket propulsion fundamentals and their applications in aerospace
- To develop skills in propulsion system testing, performance analysis, and computational modeling
- To prepare students for careers in propulsion system design, testing, and research

Course Outcomes: At the end of the course students shall be able to

CO1	Analyze advanced gas turbine components and engine-airframe integration effects
CO2	Evaluate rocket propulsion systems and their performance characteristics
C03	Conduct experimental and computational analysis of propulsion systems
C04	Design and optimize propulsion systems for specific aerospace applications

Unit	Content	Credit	Weightage
I	**ADVANCED GAS TURBINE TECHNOLOGY** • **High-Bypass Turbofan Engines**: ○ Architecture and components ○ Bypass ratio optimization ○ Fan design and performance ○ Gear systems for high bypass engines • **Advanced Compressor Design**: ○ Transonic compressors ○ Multi-stage axial compressors ○ Variable geometry compressors ○ Stall and surge control systems • **Advanced Turbine Technology**: ○ High-pressure turbine design ○ Turbine blade cooling techniques (film cooling, internal cooling) ○ Thermal barrier coatings ○ Single crystal and directionally solidified blades • **Combustion System Advancements**: ○ Lean-burn combustion ○ Low-emission combustors ○ Alternative fuels and fuel flexibility ○ Combustion instability control	1	25%

	• **Performance Enhancement Systems**: ○ Afterburners and reheat systems ○ Thrust vectoring systems ○ Noise reduction technologies • **Materials for High-Temperature Applications**: ○ Nickel-based superalloys ○ Ceramic matrix composites ○ Thermal barrier coatings		
II	**ENGINE-AIRCRAFT INTEGRATION & CONTROL** • **Inlet Design and Performance**: ○ Subsonic, transonic, and supersonic inlets ○ Boundary layer control ○ Variable geometry inlets ○ Inlet distortion and recovery • **Nozzle-Airframe Integration**: ○ Conformal nozzles ○ Thrust reversing systems ○ Noise suppression nozzles ○ IR signature reduction • **Engine Installation Effects**: ○ Nacelle design and aerodynamics ○ Pylon design considerations ○ Engine-airframe interference ○ Weight and balance effects • **Engine Control Systems**: ○ Full Authority Digital Engine Control (FADEC) ○ Control logic and algorithms ○ Fault detection and accommodation ○ Redundancy and reliability • **Engine Performance in Aircraft**: ○ Installation losses ○ Thrust lapse rate with altitude and speed ○ Fuel consumption in different flight regimes ○ Performance degradation with time • **Propulsion System Testing**: ○ Ground test facilities ○ Altitude test chambers ○ Flight testing procedures ○ Certification requirements	1	25%
III	**ROCKET PROPULSION FUNDAMENTALS** • **Rocket Fundamentals**:	1	25%

	○ Rocket equation (Tsiolkovsky equation) ○ Specific impulse and thrust coefficient ○ Mass ratio and propellant fraction ○ Staging concepts and optimization • **Chemical Rocket Propellants**: ○ Liquid propellants (cryogenic, storable) ○ Solid propellants (composite, double-base) ○ Hybrid propellants ○ Propellant properties and selection • **Liquid Rocket Engines**: ○ Engine cycles (pressure-fed, pump-fed) ○ Combustion chamber design ○ Nozzle design for high altitude ○ Cooling systems (regenerative, ablative) • **Solid Rocket Motors**: ○ Grain design and geometry ○ Burning rate control ○ Thrust-time profiles ○ Case design and materials • **Nozzle Theory for Rockets**: ○ Conical and contoured nozzles ○ Altitude compensation ○ Two-phase flow effects ○ Nozzle separation • **Advanced Rocket Concepts**: ○ Electric propulsion systems ○ Nuclear thermal propulsion ○ Air-breathing rocket engines ○ Reusable launch systems		
IV	**PROPULSION SYSTEM ANALYSIS & FUTURE TRENDS** • **Propulsion System Performance Analysis**: ○ Cycle analysis for different engine types ○ Off-design performance prediction ○ Performance deterioration modeling ○ Life cycle cost analysis • **Computational Methods in Propulsion**: ○ Computational Fluid Dynamics for engine components ○ Combustion modeling ○ Heat transfer analysis ○ Structural analysis of rotating components • **Environmental Considerations**: ○ Emission regulations (CAEP standards)	1	25%

	○ Noise regulations ○ Sustainable aviation fuels ○ Electrification of propulsion • **Emerging Technologies**: ○ Open rotor engines ○ Geared turbofans ○ Distributed propulsion ○ Boundary layer ingestion • **Propulsion for Special Applications**: ○ Unmanned aerial vehicles (UAVs) ○ Supersonic business jets ○ Hypersonic vehicles (scramjets) ○ Space propulsion systems • **Reliability and Maintenance**: ○ Failure modes and effects analysis ○ Condition monitoring systems ○ Maintenance scheduling ○ Overhaul and repair procedures • **Case Studies**: ○ Modern aircraft engine programs ○ Space launch vehicle propulsion systems ○ Engine failure investigations		

Textbooks:

- "Aircraft Propulsion" by Saeed Farokhi *Wiley, 2nd Edition*
- "Rocket Propulsion Elements" by George P. Sutton and Oscar Biblarz *Wiley, 9th Edition*
- "Gas Turbine Theory" by H.I.H. Saravanamuttoo, G.F.C. Rogers, and H. Cohen *Pearson, 7th Edition*

Reference books:

- "Aircraft Engine Design" by Jack D. Mattingly, William H. Heiser, and David T. Pratt *AIAA Education Series, 3rd Edition*
- "The Design and Development of Gas Turbine Engines" by Ivor H. T. Smith *AIAA Education Series*
- "Mechanics and Thermodynamics of Propulsion" by Philip G. Hill and Carl R. Peterson *Pearson, 2nd Edition*
- "Jet Propulsion: A Simple Guide to the Aerodynamic and Thermodynamic Design and Performance of Jet Engines" by Nicholas Cumpsty and Andrew Heyes *Cambridge University Press, 3rd Edition*
- "Modern Engineering for Design of Liquid-Propellant Rocket Engines" by Dieter K. Huzel and David H. Huang *AIAA Education Series*

Online Platforms:

NPTEL (National Programme on Technology Enhanced Learning):

- "Rocket Propulsion" by IIT Kanpur
- "Gas Turbines and Jet Propulsion" by IIT Kharagpur
- "Advanced Propulsion Systems" by IIT Bombay
- "Aerospace Propulsion" by IIT Madras

- Website: https://nptel.ac.in

PRACTICAL LIST:

Session 1: Turbofan Engine Performance Analysis 1. Bypass ratio measurement and calculation 2. Fan performance characteristics 3. Core and bypass stream analysis 4. Performance comparison with turbojet engine	**Session 7: Solid Rocket Motor Testing** 1. Small-scale solid rocket motor preparation 2. Thrust-time profile measurement 3. Specific impulse calculation 4. Burning rate determination
Session 2: Compressor Map Generation 1. Multi-stage compressor testing 2. Speed line generation 3. Surge line determination 4. Performance map creation	**Session 8: Liquid Rocket Component Testing** 1. Injector spray pattern analysis 2. Combustion chamber pressure measurement 3. Cooling channel flow analysis 4. Nozzle performance testing
Session 3: Turbine Cooling Effectiveness 1. Turbine blade temperature measurement 2. Cooling flow rate optimization 3. Heat transfer coefficient calculation 4. Thermal barrier coating effectiveness evaluation	**Session 9: Hybrid Rocket Testing** 1. Hybrid rocket motor assembly 2. Oxidizer flow control 3. Regression rate measurement 4. Performance comparison with solid and liquid rockets
Session 4: Engine Control System Implementation 1. FADEC system familiarization 2. Control algorithm implementation 3. Engine startup sequence simulation 4. Fault detection and accommodation **Session 5: Inlet Performance Testing** 1. Subsonic inlet pressure recovery measurement 2. Boundary layer control demonstration 3. Inlet distortion measurement 4. Recovery improvement techniques	**Session 10: Computational Propulsion Analysis** 1. Gas turbine cycle analysis using software 2. Rocket performance prediction 3. Combustion chamber CFD simulation 4. Heat transfer analysis of turbine blades **Session 11: Environmental Impact Analysis** 1. Engine emission measurement 2. Noise level measurement and analysis 3. Alternative fuel testing 4. Life cycle assessment of propulsion systems
Session 6: Nozzle Performance Analysis 1. Convergent-divergent nozzle testing 2. Thrust vectoring demonstration 3. Nozzle efficiency calculation 4. IR signature measurement (simulated)	**Session 12: Integrated Project** **Choose one of the following:** 1. **Engine Performance Optimization**: Optimization of engine parameters for specific mission profile 2. **Rocket Motor Design**: Complete design and analysis of small rocket motor 3. **Propulsion System Integration**: Integration study of engine with aircraft configuration 4. **Alternative Propulsion System Analysis**: Analysis of emerging propulsion technology

SUBJECT CODE: BTAE504

SUBJECT NAME: AVIONICS SYSTEMS

Course Objectives:

- To understand fundamental principles of avionics systems and their integration in modern aircraft
- To study navigation, communication, and surveillance systems used in aviation
- To analyze flight control systems, cockpit displays, and aircraft health monitoring systems
- To develop practical skills in avionics system testing, troubleshooting, and maintenance
- To prepare students for careers in aircraft avionics design, maintenance, and certification

Course Outcomes: At the end of the course students shall be able to

CO1	Analyze aircraft communication, navigation, and surveillance systems
CO2	Evaluate flight control systems, cockpit displays, and aircraft health monitoring systems
C03	Conduct testing, troubleshooting, and maintenance of avionics systems
C04	Design and integrate avionics systems for specific aircraft applications

PRACTICAL LIST:

Session 1: VHF Communication System
1. VHF transceiver operation and testing
2. Frequency selection and tuning
3. Transmitter power measurement
4. Receiver sensitivity testing

Session 2: HF Communication System
1. HF radio system operation
2. Antenna tuning and matching
3. Ground wave and sky wave propagation study
4. SELCAL (Selective Calling) system testing

Session 3: Data Communication Systems
1. ACARS (Aircraft Communications Addressing and Reporting System) operation
2. VHF Data Link (VDL) system testing
3. SATCOM system familiarization
4. Data communication protocols analysis

Session 4: VOR/ILS Navigation
1. VOR (VHF Omnidirectional Range) receiver testing
2. ILS (Instrument Landing System) localizer and glideslope testing
3. DME (Distance Measuring Equipment) operation
4. Navigation accuracy measurement

Session 5: GPS/INS Integration
1. GPS receiver performance testing

Session 7: Flight Control System Testing
1. Fly-by-wire system components identification
2. Control law implementation and testing
3. Feedback system analysis
4. Control surface actuator testing

Session 8: Cockpit Display Systems
1. EFIS (Electronic Flight Instrument System) operation
2. PFD (Primary Flight Display) and MFD (Multi-Function Display) testing
3. HUD (Head-Up Display) system familiarization
4. Display symbology and format customization

Session 9: Autopilot System
1. Autopilot mode selection and engagement
2. Flight director system testing
3. Autopilot servo operation
4. Mode control panel testing

Session 10: Surveillance Systems
1. Transponder system operation and testing
2. TCAS (Traffic Alert and Collision Avoidance System) simulation
3. Weather radar system operation
4. ADS-B (Automatic Dependent Surveillance-Broadcast) system testing

Session 11: Aircraft Health Monitoring
1. Flight Data Recorder (FDR) system

2. INS (Inertial Navigation System) drift analysis 3. GPS/INS integration demonstration 4. Navigation solution accuracy comparison Session 6: Radio Altimeter and ADF 1. Radio altimeter operation and calibration 2. ADF (Automatic Direction Finder) system testing 3. NDB (Non-Directional Beacon) signal reception 4. Navigation system integration exercise	familiarization 2. Engine vibration monitoring system testing 3. Structural health monitoring demonstration 4. Maintenance data analysis Session 12: Integrated Project Choose one of the following: 1. Avionics System Integration: Integration of navigation and communication systems 2. Flight Control System Design: Design of basic autopilot system 3. Cockpit Display Design: Design of PFD/MFD interface 4. Aircraft Health Monitoring System: Development of basic health monitoring system

SUBJECT CODE: BTAE505

SUBJECT NAME: WIND TUNNEL TESTING

Course Objectives:

- To understand fundamental principles and methodologies of wind tunnel testing in aerospace engineering
- To study different types of wind tunnels and their applications for various aerodynamic investigations
- To develop skills in experimental setup, instrumentation, data acquisition, and analysis for wind tunnel experiments
- To apply wind tunnel testing techniques to solve practical aerodynamic problems
- To prepare students for careers in experimental aerodynamics, aircraft testing, and research

Course Outcomes: At the end of the course students shall be able to

CO1	Analyze wind tunnel types, components, and operational principles for different aerodynamic testing applications
CO2	Design and setup wind tunnel experiments with appropriate instrumentation and measurement techniques
C03	Conduct aerodynamic testing, data acquisition, and analysis for various aerospace configurations
C04	Design comprehensive wind tunnel test programs and analyze results for engineering applications

PRACTICAL LIST:

Session 1: Wind Tunnel Familiarization and Calibration 1. Identification of wind tunnel components (settling chamber, contraction cone, test section, diffuser, fan/motor) 2. Wind tunnel calibration procedures 3. Measurement of test section velocity profile 4. Determination of turbulence intensity and flow uniformity **Session 2: Flow Visualization Techniques** 1. Smoke wire visualization setup and operation	**Session 7: Wing Performance Testing** 1. Testing of wings with different aspect ratios 2. Effect of taper ratio on aerodynamic performance 3. Swept wing testing at various angles 4. Wingtip vortex visualization and analysis **Session 8: High-Lift Device Testing** 1. Testing of plain flaps 2. Slotted flap performance analysis 3. Effect of flap deflection on lift and drag 4. Optimal flap setting determination

2. Tuft grid visualization for surface flow patterns
3. Oil flow visualization for boundary layer studies
4. Particle Image Velocimetry (PIV) demonstration (if available)

Session 3: Pressure Measurement Fundamentals

1. Pitot-static tube calibration and operation
2. Multi-tube manometer setup and reading
3. Pressure tap installation and measurement
4. Surface pressure distribution measurement

Session 4: Force Balance Calibration and Operation

1. Six-component strain gauge balance calibration
2. Wind-off zero measurements and tare procedures
3. Static calibration with known weights
4. Dynamic response testing

Session 5: Lift and Drag Measurement

1. Airfoil lift and drag measurement at various angles of attack
2. Determination of lift curve slope
3. Drag polar construction
4. Stall characteristics analysis

Session 6: Pitching Moment and Center of Pressure

1. Pitching moment measurement for airfoils
2. Center of pressure determination
3. Aerodynamic center location
4. Moment coefficient calculation

Session 9: Complete Aircraft Model Testing

1. Testing of scaled aircraft models
2. Longitudinal stability analysis
3. Lateral-directional characteristics
4. Complete aircraft drag polar construction

Session 10: Boundary Layer Studies

1. Boundary layer thickness measurement using pitot probe
2. Velocity profile measurement near surface
3. Determination of displacement and momentum thickness
4. Boundary layer transition observation

Session 11: Special Flow Phenomena

1. Flow separation visualization
2. Vortex generation and shedding studies
3. Shock wave visualization (in supersonic tunnel if available)
4. Cavitation studies (in water tunnel if available)

Session 12: Integrated Project

Choose one of the following:

1. **Aircraft Component Optimization**: Wind tunnel testing for performance optimization
2. **New Configuration Testing**: Testing of novel aerodynamic configuration
3. **Scale Effects Study**: Investigation of Reynolds number effects
4. **Comparative Analysis**: Comparison of computational and experimental results

SEMESTER-VI

SUBJECT CODE: BTAE601

SUBJECT NAME: FLIGHT DYNAMICS AND CONTROL

Course Objectives:

- To understand aircraft dynamic behavior and stability characteristics in various flight regimes
- To analyze aircraft equations of motion and develop mathematical models for flight dynamics
- To study aircraft stability augmentation systems and automatic flight control systems
- To design and analyze flight control systems for stability and performance requirements
- To develop experimental and computational skills for flight dynamics analysis and control system design

Course Outcomes: At the end of the course students shall be able to

CO1	Formulate aircraft equations of motion and analyze stability derivatives
CO2	Evaluate aircraft dynamic modes and stability characteristics
C03	Design and analyze stability augmentation and flight control systems
C04	Conduct flight simulation and control system implementation for aircraft dynamics

Unit	Content	Credit	Weightage
I	**AIRCRAFT EQUATIONS OF MOTION & STABILITY DERIVATIVES** • **Coordinate Systems and Transformations**: ○ Earth-centered inertial frame ○ Earth-fixed frame ○ Body-fixed frame ○ Wind axes frame ○ Euler angles and quaternion representations • **Rigid Body Dynamics**: ○ Newton-Euler equations of motion ○ Linear and angular momentum ○ Inertia tensor and moments of inertia • **Aircraft Equations of Motion**: ○ Six-degree-of-freedom equations ○ Force and moment equations ○ Small perturbation theory ○ Linearized equations of motion • **Stability and Control Derivatives**: ○ Longitudinal derivatives (Xu, Zu, Mu, Xw, Zw, Mw, etc.) ○ Lateral-directional derivatives (Yv, Lv, Nv, Yp, Lp, Np, Yr, Lr, Nr)	1	25%

	○ Control derivatives (Xδe, Zδe, Mδe, Yδa, Lδa, Nδa, etc.) ○ Methods for derivative estimation • **Dimensional vs Non-dimensional Derivatives**: ○ Conversion relationships ○ Physical significance ○ Experimental determination methods • **Atmospheric and Gravitational Effects**: ○ Standard atmosphere considerations ○ Gravity gradient effects ○ Earth rotation effects (for high-speed aircraft)		
II	**AIRCRAFT DYNAMIC MODES & STABILITY ANALYSIS** • **Longitudinal Dynamics**: ○ Decoupling of longitudinal equations ○ Characteristic equation for longitudinal motion ○ Short period mode characteristics ○ Phugoid mode characteristics ○ Mode approximation methods • **Lateral-Directional Dynamics**: ○ Decoupling of lateral-directional equations ○ Dutch roll mode characteristics ○ Roll mode characteristics ○ Spiral mode characteristics • **Stability Criteria**: ○ Routh-Hurwitz stability criteria ○ Eigenvalue analysis ○ Mode shapes and eigenvectors ○ Natural frequencies and damping ratios • **Aircraft Handling Qualities**: ○ Cooper-Harper rating scale ○ Military specifications (MIL-STD-1797) ○ Civil aircraft handling requirements ○ Pilot-induced oscillations • **Stability Augmentation Systems (SAS)**: ○ Yaw damper systems ○ Pitch damper systems ○ Roll damper systems ○ Stability derivative feedback • **Effect of Configuration Changes**: ○ Fuel burn effects	1	25%

	○ Control surface failures ○ Atmospheric disturbances ○ Weight and balance variations		
III	**FLIGHT CONTROL SYSTEM DESIGN** • **Control System Fundamentals Review**: ○ Transfer functions and state-space representation ○ Frequency response analysis ○ Root locus techniques ○ Nyquist stability criterion • **Autopilot Systems**: ○ Pitch attitude hold ○ Altitude hold ○ Heading hold ○ Speed/Mach hold ○ Navigation mode coupling • **Flight Control Laws**: ○ Proportional-Integral-Derivative (PID) control ○ Optimal control theory applications ○ Robust control techniques ○ Adaptive control systems • **Control Allocation**: ○ Redundant control surfaces ○ Control mixing algorithms ○ Fault-tolerant control allocation ○ Control surface effectiveness • **Fly-by-Wire Systems**: ○ Architecture and components ○ Control law implementation ○ Redundancy and reliability ○ Failure detection and accommodation • **Modern Control Techniques**: ○ State feedback control ○ Observer design ○ LQR/LQG control ○ H-infinity control • **Human-Machine Interface**: ○ Control stick characteristics ○ Force-feel systems ○ Sidestick controllers ○ Control sensitivity adjustment	1	25%
IV	**ADVANCED TOPICS & INTEGRATED DESIGN**	1	25%

	• **Nonlinear Flight Dynamics**: o Large amplitude maneuvers o Spin dynamics and recovery o Stall and post-stall behavior o Limit cycle oscillations • **Aeroelastic Effects**: o Control surface reversal o Flutter analysis o Structural mode coupling o Active flutter suppression • **Atmospheric Disturbances**: o Gust and turbulence modeling o Wind shear effects o Microburst encounter o Mountain wave effects • **Fault Detection and Diagnosis**: o Sensor failure detection o Actuator failure accommodation o System reconfiguration o Emergency control laws • **Unmanned Aerial Vehicle (UAV) Dynamics**: o Special considerations for UAVs o Autonomous flight control o Path planning and following o Swarm dynamics • **Flight Testing for Dynamics**: o Dynamic stability tests o Control system evaluation o Handling qualities assessment o Certification requirements • **Future Trends**: o Artificial intelligence in flight control o Neural network controllers o Distributed control systems o Autonomous aircraft operations		

Textbooks:

- "Flight Dynamics" by Robert F. Stengel *Princeton University Press*
- "Aircraft Control and Simulation" by Brian L. Stevens, Frank L. Lewis, and Eric N. Johnson *Wiley, 3rd Edition*
- "Dynamics of Flight: Stability and Control" by Bernard Etkin and Lloyd D. Reid *Wiley, 3rd Edition*

Reference books:

- "Aircraft Dynamics and Automatic Control" by Duane T. McRuer, Irving Ashkenas, and Dunstan Graham *Princeton University Press*

- "Flight Stability and Automatic Control" by Robert C. Nelson *McGraw-Hill, 2nd Edition*
- "Introduction to Aircraft Flight Dynamics" by Louis V. Schmidt *AIAA Education Series*
- "Aircraft System Identification: Theory and Practice" by Eugene A. Morelli and Vladislav Klein *AIAA Education Series, 2nd Edition*
- "Modern Flight Dynamics" by David K. Schmidt *McGraw-Hill*

Online Platforms:

NPTEL (National Programme on Technology Enhanced Learning):

- "Flight Dynamics" by IIT Kanpur
- "Automatic Control Systems" by IIT Bombay
- "Aircraft Stability and Control" by IIT Kharagpur
- "Modern Control Theory" by IIT Madras
- Website: https://nptel.ac.in

PRACTICAL LIST:

Session 1: Aircraft Mathematical Model Development 1. Development of 6-DOF aircraft equations of motion in MATLAB 2. Implementation of stability and control derivatives 3. Linearization of equations for small perturbations 4. State-space representation development Session 2: Flight Simulation Setup 1. Integration of aircraft model with flight simulator 2. Real-time simulation implementation 3. Data logging and visualization setup 4. Model validation with known flight data Session 3: Stability Derivative Estimation 1. Parameter estimation from flight test data 2. Least squares estimation techniques 3. Derivative calculation from wind tunnel data 4. Uncertainty analysis of estimated parameters Session 4: Longitudinal Dynamics Analysis 1. Short period mode identification and analysis 2. Phugoid mode characteristics study 3. Effect of center of gravity position on stability 4. Stability boundary determination Session 5: Lateral-Directional Dynamics Analysis 1. Dutch roll mode identification 2. Roll and spiral mode analysis 3. Dihedral effect study	Session 7: Autopilot Design and Implementation 1. Pitch attitude hold system design 2. Altitude hold control system 3. Heading hold implementation 4. Control law tuning and optimization Session 8: Stability Augmentation Systems 1. Yaw damper design and implementation 2. Pitch damper system development 3. Roll damper integration 4. SAS effectiveness evaluation Session 9: Fly-by-Wire System Simulation 1. Control law implementation in Simulink 2. Control allocation algorithms 3. Redundancy management 4. Failure simulation and accommodation Session 10: Nonlinear Dynamics and Control 1. Large amplitude maneuver simulation 2. Spin dynamics and recovery analysis 3. Stall and post-stall behavior study 4. Nonlinear control system design Session 11: Disturbance Rejection and Robust Control 1. Gust and turbulence modeling 2. Disturbance rejection controller design 3. Robust control implementation 4. Performance evaluation under disturbances Session 12: Integrated Project Choose one of the following: 1. Complete Flight Control System Design: Design of integrated flight control system 2. Aircraft Handling Qualities Improvement: Redesign for improved handling qualities 3. Autonomous Flight System: Development of

4. Weathercock stability evaluation Session 6: Handling Qualities Assessment 1. Cooper-Harper rating application 2. Pilot-in-the-loop simulation 3. Handling qualities metrics calculation 4. Pilot-induced oscillation study	autonomous flight control system 4. Fault-Tolerant Control System: Design of system with failure accommodation

SUBJECT CODE: BTAE602

SUBJECT NAME: AEROSPACE VEHICLE DESIGN

Course Objectives:

- Introduce students to the philosophy, process, and stages of aerospace vehicle design.
- Develop the ability to formulate design specifications based on mission requirements.
- Impart knowledge of preliminary sizing, configuration layout, and component design for fixed-wing aircraft.
- Equip students with analytical and empirical methods for aerodynamic, propulsive, structural, and performance estimation during conceptual design.
- Foster system-level thinking and the integration of stability, control, and basic systems considerations in initial design.
- Provide hands-on experience through design projects and case studies of existing aircraft.

Course Outcomes: At the end of the course students shall be able to

CO1	Introduce students to the philosophy, process, and stages of aerospace vehicle design.
CO2	Develop the ability to formulate design specifications based on mission requirements.
C03	Impart knowledge of preliminary sizing, configuration layout, and component design for fixed-wing aircraft.
C04	Equip students with analytical and empirical methods for aerodynamic, propulsive, structural, and performance estimation during conceptual design.

Unit	Content	Credit	Weightage
I	**Module 1: Introduction to Aircraft Design Process** • The design process: **Conceptual, Preliminary, and Detailed Design** phases. • Requirements definition: Customer needs, market analysis, design specifications (Airworthiness standards: FAR/CS-23, 25). • **Weight estimation:** Methods for historical, statistical, and component-based weight prediction. • **Preliminary sizing:** Estimation of take-off weight, wing loading, and thrust-to-weight ratio using	1	25%

	performance constraints (stall speed, take-off, climb, cruise, landing). • **Configuration selection:** Choices of wing (high/low, sweep, airfoil), tail (conventional, T-tail, H-tail, canard), landing gear, and propulsion layout.		
II	**Module 2: Aerodynamic and Propulsion Considerations** • **Airfoil and wing geometry selection:** Planform, aspect ratio, taper ratio, twist. • **Drag estimation:** Breakdown into parasite drag (skin friction, form, interference) and induced drag. Use of **equivalent skin-friction coefficient** and **component build-up method**. • **High-lift devices:** Types and impact on take-off & landing performance. • **Propulsion system selection:** Piston-prop, turboprop, turbofan, turbojet. Engine matching and installation effects. • **Intake and nozzle considerations** for jet aircraft.	1	25%
III	**Module 3: Layout Design, Structures & Systems Integration** • **Configuration layout and lofting:** Creating three-view drawings, component placement for balance. • **Center of gravity estimation** and control. • **Introduction to structural layout:** Load paths, material selection (Al alloys, Composites, Ti), typical structural arrangements (wing box, fuselage frames/longerons). • **Landing gear design:** Geometry, retraction, and sizing. • **Introduction to essential systems:** Flight controls (mechanical, FBW), hydraulic, electrical, and fuel systems in design context.	1	25%
IV	**Module 4: Stability, Control, and Performance Analysis** • **Static stability:** Longitudinal, lateral, and directional stability estimates from configuration. • **Control surfaces:** Sizing for pitch, roll, and yaw control (elevator, aileron, rudder). • **Performance analysis:** Developing the **constraint diagram**. Detailed analysis of mission segments (take-off, climb, cruise, descent, loiter, landing).	1	25%

	• **Range and endurance** calculations (Breguet equations). • **Case studies:** Design analysis of a historical or contemporary aircraft (e.g., Cessna 172, Airbus A320, UAV).		

Textbooks:

- Aircraft Design: A Conceptual Approach – Daniel P. Raymer. (AIAA Education Series) *(Primary Text)*
- Introduction to Flight – John D. Anderson Jr. (McGraw-Hill) *(For foundational concepts)*
- Jane's All the World's Aircraft (Annual Publication) *(For reference data)*

Reference books:

- Airplane Design Parts I-VIII – Jan Roskam. (DARcorporation)
- Synthesis of Subsonic Airplane Design – Egbert Torenbeek. (Delft University Press)
- Design of Aircraft – Thomas C. Corke. (Pearson)
- The Anatomy of the Aeroplane – Darrol Stinton.
- Fundamentals of Aircraft and Airship Design, Volume I: Aircraft Design – Leland M. Nicolai & Grant E. Carichner. (AIAA)

Online Platforms:

- Coursera/edX: Courses on aerodynamics, flight mechanics, and introduction to aerospace engineering

PRACTICAL LIST:

- Preliminary Sizing of a Trainer Aircraft: Given mission requirements (payload, range, endurance, cruise speed, field length), estimate Take-Off Gross Weight (TOGW), Wing Area, and Engine Power/Thrust.
- Constraint Analysis and Wing Loading Diagram: Plot thrust-to-weight vs. wing loading for key performance constraints (stall, take-off, climb, cruise, landing) to identify the feasible design space.
- Configuration Layout & Three-View Drawing: Create a scaled three-view drawing (CAD or manual) of a designed aircraft, showing wing, tail, fuselage, landing gear, and engine placement.
- Drag Polar Estimation: Calculate the drag polar (CD vs. CL) for the designed aircraft using component build-up methods, identifying zero-lift drag and induced drag factors.

SUBJECT CODE: BTAE603

SUBJECT NAME: HEAT TRANSFER

Course Objectives:

- Introduce the fundamental modes of heat transfer (conduction, convection, radiation) and their governing laws.
- Develop the ability to formulate and solve steady and transient heat conduction problems in aerospace components.
- Impart knowledge of forced and natural convection principles with applications to external and internal flows over surfaces, fins, and ducts.
- Explain the fundamentals of thermal radiation and its role in aerospace systems.
- Introduce heat exchanger analysis and design methodology.
- Provide hands-on experience through experiments that illustrate heat transfer principles relevant to aeronautical systems.

Course Outcomes: At the end of the course students shall be able to

CO1	Explain the mechanisms and governing laws of the three modes of heat transfer.
CO2	Analyze and solve one-dimensional and two-dimensional steady-state and transient conduction problems.
C03	Apply empirical correlations to solve convection heat transfer problems for external and internal flows.
C04	Analyze radiation heat exchange between surfaces and apply it to aerospace thermal systems.

Unit	Content	Credit	Weightage
I	**Conduction Heat Transfer** • **Introduction:** Modes of heat transfer. Basic laws (Fourier's, Newton's, Stefan-Boltzmann). Combined modes. • **Steady-State Conduction:** 1D conduction in plane walls, cylinders, and spheres (composite layers). Thermal resistance networks. • **Finned Surfaces:** Fin equation, fin efficiency, and effectiveness. Applications to cooling. • **Transient Conduction:** Lumped capacitance method (Biot number criterion). Introduction to 1D transient solutions (Heisler charts).	1	25%
II	**Convection - Fundamentals & Forced Convection** • **Convection Fundamentals:** Physical mechanism. Velocity and thermal boundary layers. Key dimensionless numbers (Re, Pr, Nu, St). • **Forced Convection - External Flow:** Laminar and turbulent flow over flat plates. Flow across cylinders and spheres (relevant to fuselage, struts). • **Forced Convection - Internal Flow:** Hydrodynamic and thermal entry lengths. Flow in tubes (relevant to aircraft ducts, heat exchanger tubes). Constant surface temperature vs. constant heat flux conditions. • High-speed flows: Introduction to **aerodynamic heating and recovery factor**.	1	25%
III	**Natural Convection & Heat Exchangers** • **Natural Convection:** Physical mechanism. Governing equations and Grashof number.	1	25%

	• Empirical correlations for vertical and horizontal plates, cylinders, and enclosed spaces. • Combined free and forced convection. • **Heat Exchangers:** Types (parallel, counter, cross-flow). Log Mean Temperature Difference (LMTD) method. Effectiveness-NTU (ε-NTU) method. • Compact heat exchangers in aerospace.		
IV	**Radiation Heat Transfer** • **Fundamentals:** Thermal radiation spectrum. Blackbody radiation (Planck's, Wien's, Stefan-Boltzmann laws). • **Surface Properties:** Emissivity, absorptivity, reflectivity, transmissivity. Kirchhoff's law. • **Radiation Exchange:** View factor concept and algebra. Radiation exchange between black surfaces. • Radiation exchange between diffuse, gray surfaces in an enclosure (radiation shields, re-radiating surfaces). • Introduction to **solar radiation** and **atmospheric re-entry heating** concepts.	1	25%

Textbooks:

- Fundamentals of Heat and Mass Transfer – Frank P. Incropera, David P. DeWitt, Theodore L. Bergman, Adrienne S. Lavine. (Wiley) *(Primary Text)*
- Heat and Mass Transfer: Fundamentals & Applications – Yunus A. Çengel, Afshin J. Ghajar. (McGraw-Hill)
- Heat Transfer – J.P. Holman. (McGraw-Hill)

Reference books:

- A Heat Transfer Textbook – John H. Lienhard IV & John H. Lienhard V. (Phlogiston Press) *[Freely available online]*.
- Principles of Heat Transfer – Frank Kreith, Raj M. Manglik, Mark S. Bohn. (Cengage Learning)
- Thermal Radiation Heat Transfer – John R. Howell, M. Pinar Mengüç, Kyle Daun, Robert Siegel. (CRC Press)
- Boundary Layer Theory – Hermann Schlichting, Klaus Gersten. (Springer) – *For advanced convection topics*.

Online Platforms:

- NPTEL (India) Web Course: "Heat and Mass Transfer" by Prof. S.K. Som.
- MIT Open Course Ware: Courses like "Transport Processes" (2.051) or "Heat Transfer" (2.005).
- edX / Coursera: "Introduction to Engineering Heat Transfer" or similar.

PRACTICAL LIST:

- Thermal Conductivity Measurement: Determination of thermal conductivity of a metal rod using guarded hot plate method.

- Forced Convection: Study of heat transfer from a cylinder/plate in a wind tunnel. Determination of Nusselt number correlation with Reynolds number.
- Natural Convection: Determination of heat transfer coefficient from a vertical/horizontal heated cylinder or plate in ambient air.
- Heat Exchanger Performance: Performance analysis of a parallel-flow and counter-flow tube-in-tube heat exchanger. Calculation of LMTD and effectiveness.

SUBJECT CODE: BTAE604

SUBJECT NAME: UAV SYSTEMS

Course Objectives:

- Introduce the fundamental concepts, classifications, and components of Unmanned Aerial Vehicle (UAV) systems.
- Provide comprehensive knowledge of UAV aerodynamics, flight mechanics, and propulsion systems specific to unmanned platforms.
- Explain the principles and technologies behind autonomous flight control systems, guidance, navigation, and sensing.
- Examine communication systems, data links, ground control stations, and payloads used in UAV operations.
- Familiarize students with UAV mission planning, operational procedures, and regulatory frameworks.
- Develop system-level understanding of UAV design trade-offs and emerging applications in defense and civilian sectors.

Course Outcomes: At the end of the course students shall be able to

CO1	Classify UAV types based on configuration, range, endurance, and mission profiles.
CO2	Analyze the aerodynamic characteristics and flight mechanics of fixed-wing and multi-rotor UAVs.
C03	Describe the architecture of autopilot systems, sensors (IMU, GPS), and flight control algorithms.
C04	Explain communication systems, data links, and ground control station operations.

Unit	Content	Credit	Weightage
I	**UAV Fundamentals, Aerodynamics & Propulsion Systems** • **Introduction & Classification:** History, terminology (UAV, UAS, RPA, Drone). Classification by configuration (fixed-wing, rotary-wing, hybrid VTOL), size, range, and endurance. • **UAV System Architecture:** Complete system components: Air vehicle, ground control station (GCS), communication data link, launch & recovery systems.	1	50%

	• **UAV Aerodynamics:** Low Reynolds number aerodynamics. Wing loading considerations. Stability and control derivatives specific to small UAVs. • **UAV Configurations:** Fixed-wing, rotary-wing (single/multi-rotor), flapping-wing (ornithopters). Comparison of performance and applications. • **Propulsion Systems:** Electric propulsion (brushless DC motors, Li-Po batteries). Internal combustion engines for UAVs. Propeller selection and performance. • **Design Considerations:** Preliminary sizing, weight estimation, endurance and range calculations for electric UAVs.		
II	**UAV Avionics, Autonomy, Communications & Operations** • **Flight Control & Autopilot Systems:** Autopilot architecture (Pixhawk, Ardupilot). Sensors: IMU (Accelerometer, Gyro, Magnetometer), GPS, Air data sensors. Flight control laws (PID controllers). • **Guidance, Navigation & Control (GNC):** Waypoint navigation. Autonomous take-off, landing, and mission execution. Fail-safe modes (RTL, Loiter). • **Communication Systems & Data Links:** RF spectrum, LOS/BLOS communication. Data link architecture (uplink, downlink). Telemetry and video transmission. Antenna types. • **Payloads:** Electro-optical/Infrared (EO/IR) cameras, LiDAR, multispectral sensors, SAR. Payload integration and gimbal stabilization. • **Ground Control Station (GCS):** Software (Mission Planner, QGroundControl). Human-Machine Interface (HMI). Mission planning and monitoring. • **Regulations & Operations:** DGCA CAR Section 3 - Series X, Part I (or relevant FAA Part 107). Airspace classes, VLOS/BVLOS operations. Safety, security, and ethical considerations. • **Applications & Future Trends:** Military, civilian, and commercial applications. Swarm UAVs, AI/ML in UAVs, airspace integration (UTM).	1	50%

Textbooks:

- Introduction to UAV Systems – Paul G. Fahlstrom, Thomas J. Gleason. (Wiley) *(Primary Text)*
- Unmanned Aircraft Systems: UAVS Design, Development and Deployment – Reg Austin. (Wiley)

- Small Unmanned Aircraft: Theory and Practice – Randal W. Beard, Timothy W. McLain. (Princeton University Press)

Reference books:

- Design of Unmanned Air Vehicle Systems – Denis L. Bourell. (Lockheed Martin)
- Handbook of Unmanned Aerial Vehicles – Kimon P. Valavanis, George J. Vachtsevanos (Eds.). (Springer)
- UAV Sensors for Environmental Monitoring – Felipe Gonzalez Toro, Antonios Tsourdos. (MDPI Books)
- DGCA Civil Aviation Requirements (CAR Section 3, Series X, Part I) – *Official Regulatory Document*.

Online Platforms:

- NPTEL Course: "Unmanned Aerial Vehicle" by Prof. C. Venkatesan (IIT Kanpur).

SUBJECT CODE: BTAE605

SUBJECT NAME: FLIGHT SIMULATION LAB

Course Objectives:

- Provide hands-on experience with professional flight simulation software and hardware interfaces.
- Demonstrate fundamental aircraft flight dynamics, stability, and control principles through simulation.
- Develop skills in performing standard flight maneuvers and analyzing aircraft responses.
- Introduce mission planning, navigation procedures, and emergency scenario management in simulated environments.
- Foster understanding of aircraft performance parameters under various flight conditions.
- Bridge theoretical aeronautical knowledge with practical piloting and testing procedures.

Course Outcomes: At the end of the course students shall be able to

CO1	Operate flight simulation software and interpret primary flight display (PFD) and navigation display (ND) instruments.
CO2	Execute and analyze standard flight maneuvers (climb, turn, descent, approach) and evaluate aircraft stability.
C03	Plan and execute VFR and IFR navigation flights using waypoints, VOR, and ILS systems.
C04	Analyze aircraft performance characteristics (stall speed, climb rate, turn radius) from simulated flight data.

PRACTICAL LIST:

- **Lab 1: Simulator Familiarization & Cockpit Orientation**
  - Introduction to simulation software/hardware (e.g., X-Plane/MSFS with add-ons).
  - Understanding primary flight instruments: Airspeed Indicator, Altimeter, Attitude Indicator, Heading Indicator, etc.
  - Basic aircraft control using yoke/joystick and throttle: Achieving and maintaining straight-and-level flight.
- **Lab 2: Aircraft Performance in Straight Flight**
  - Determination of trim conditions for level flight at different airspeeds.
  - Performing climbs and descents at various airspeeds and power settings.
  - Measurement of rate of climb/descent and associated power required.
- **Lab 3: Turning Flight & Coordinated Maneuvers**

  - Executing standard rate turns (3° per second) and understanding turn coordinator.
  - Analysis of turn radius and rate vs. bank angle and airspeed.
  - Practice of coordinated turns using rudder and aileron.
- **Lab 4: Longitudinal & Lateral-Directional Stability Demonstration**
  - Static stability test: Aircraft response to pitch, roll, and yaw disturbances.
  - Phugoid and short-period mode observation.
  - Dutch roll and spiral mode observation (for applicable aircraft).
- **Lab 5: VFR Navigation & Mission Planning**
  - Planning a cross-country VFR flight using sectional charts.
  - Execution of planned flight with visual checkpoints, maintaining heading and altitude.
- **Lab 6: IFR Navigation & Instrument Approaches**
  - Intercepting and tracking VOR radials.
  - Flying a holding pattern.
  - Performing a full ILS (Instrument Landing System) approach to minimums.
- **Lab 7: Take-off & Landing Performance Analysis**
  - Measurement of ground roll and total distance for take-off under different weights and flap settings.
  - Approach and landing: Effect of flap configuration on approach speed and landing distance.
  - Crosswind take-off and landing technique practice.
- **Lab 8: Emergency Procedures & Aircraft Comparison**
  - Engine failure after take-off: Procedure practice and glide distance analysis.
    Partial panel flight (simulated instrument failure).
  - Comparative analysis of flight characteristics between a light aircraft (Cessna 172) and a transport category aircraft (Boeing 737/Airbus A320) or a fighter aircraft (basic maneuvers).

SEMESTER-VII

SUBJECT CODE: BTAE701

SUBJECT NAME: COMPUTATIONAL FLUID DYNAMICS

Course Objectives:

- Introduce the fundamental philosophy, governing equations, and numerical methodologies of CFD.
- Develop understanding of finite difference and finite volume discretization techniques for partial differential equations.
- Impart practical skills in grid generation, flow simulation setup, solver execution, and post-processing using commercial/open-source software.
- Analyze convergence, stability, accuracy, and turbulence modeling considerations in CFD.
- Apply CFD techniques to solve basic aerodynamic and incompressible flow problems relevant to aeronautical engineering.
- Critically evaluate CFD results through validation and verification against analytical/experimental data.

Course Outcomes: At the end of the course students shall be able to

CO1	Derive and explain the integral and differential forms of the **governing equations** (continuity, momentum, energy) for fluid flow.
CO2	Apply **finite difference and finite volume methods** to discretize simple partial differential equations.
C03	Generate structured **2D/3D grids** for basic geometries using meshing software.
C04	Set up, solve, and post-process **basic external and internal flow simulations** using CFD software (e.g., ANSYS Fluent/OpenFOAM).

Unit	Content	Credit	Weightage
I	**Mathematical Foundation & Governing Equations** • **Introduction:** CFD philosophy, stages (pre-processing, solving, post-processing), applications in aerospace. • **Governing Equations:** Derivation of conservation laws (mass, momentum, energy) in integral and differential forms. Navier-Stokes equations. • **Mathematical Classification of PDEs:** Elliptic, parabolic, hyperbolic equations. Initial and boundary conditions. • **Introduction to Discretization:** Overview of Finite Difference, Finite Volume, and Finite Element Methods.	1	25%
II	**Discretization & Numerical Methods**	1	25%

	• **Finite Difference Method (FDM):** Discretization of 1D and 2D Laplace/Poisson equations. Taylor series truncation error. • **Finite Volume Method (FVM):** Basic philosophy—integration over control volumes. Approximation of surface and volume integrals. • **Solution Algorithms:** Explicit vs. implicit methods. Introduction to pressure-velocity coupling (SIMPLE algorithm concept). • **Convergence, Consistency & Stability:** Lax Equivalence Theorem. Stability analysis (von Neumann method - concept only).		
III	**Grid Generation & Turbulence Modeling** • **Grid/Mesh Generation:** Types of grids (structured vs. unstructured, hexahedral vs. tetrahedral). Grid quality metrics (aspect ratio, skewness, orthogonality). • **Boundary Conditions:** Inlet (velocity, pressure), outlet (pressure-outflow), wall (no-slip, slip), symmetry. • **Introduction to Turbulence:** Reynolds-Averaged Navier-Stokes (RANS) equations. Turbulence modeling hierarchy. • **RANS Turbulence Models:** Mixing length, Standard k-ε, and SST k-ω models. Selection guidelines.	1	25%
IV	**Applications, Solver Settings & Post-Processing** • **CFD Solution Procedure:** Step-by-step setup for a typical problem in commercial software. • **Solver Settings:** Choice of solver (pressure-based vs. density-based), discretization schemes (first vs. second order), under-relaxation factors. • **Verification & Validation (V&V):** Definitions and procedures. Grid independence study. • **Post-Processing:** Visualization of contours, vectors, streamlines, and XY plots. Calculation of integral quantities (forces, moments). • **Application Case Studies:** Flow over a flat plate (boundary layer), airfoil (lift & drag), and internal duct flow.	1	25%

Textbooks:

- Computational Fluid Dynamics: The Basics with Applications – John D. Anderson, Jr. (McGraw-

Hill) *(Primary Text)*
- An Introduction to Computational Fluid Dynamics: The Finite Volume Method – H.K. Versteeg and W. Malalasekera. (Pearson)
- ANSYS Fluent User's Guide (Software Documentation)

Reference books:
- Numerical Heat Transfer and Fluid Flow – Suhas V. Patankar. (Taylor & Francis)
- Turbulence Modeling for CFD – David C. Wilcox. (DCW Industries)
- OpenFOAM User Guide – The OpenFOAM Foundation.
- Handbook of Grid Generation – Joe F. Thompson, Bharat K. Soni, Nigel P. Weatherill. (CRC Press)

Online Platforms:
- NPTEL Course: "Computational Fluid Dynamics" by Prof. S. A. Sherif.

PRACTICAL LIST:
- Flow Over a Backward-Facing Step: 2D simulation to study separation and reattachment. Grid generation in ANSYS Meshing. Visualization of recirculation zones and comparison of velocity profiles at different locations.
- Subsonic Flow Over a NACA Airfoil: 2D external aerodynamics simulation. Calculation of pressure coefficient (Cp) distribution, lift and drag coefficients at various angles of attack. Comparison with potential flow/inviscid results.
- Grid Independence Study for Internal Pipe Flow: 3D laminar/turbulent flow simulation. Quantification of centerline velocity and pressure drop across multiple grid resolutions to establish grid-independent solution.
- Comparative Study of Turbulence Models: Flow over a 2D cylinder. Simulation using Standard k-ε and SST k-ω models. Comparison of drag coefficient and Strouhal number with experimental data to assess model performance.

SUBJECT CODE: BTAE702

SUBJECT NAME: AIRCRAFT SYSTEMS ENGINEERING

Course Objectives:
- Provide a holistic, systems-level understanding of modern aircraft as an integrated assembly of interacting subsystems.
- Introduce the principles, architecture, and operation of major aircraft systems: hydraulic, pneumatic, electrical, fuel, environmental control, ice protection, and flight control.
- Explain the design requirements, redundancy management, and safety considerations (ARP4754, DO-178, DO-254) for safety-critical aircraft systems.
- Develop knowledge of avionics systems, cockpit displays, and emerging technologies (Fly-By-Wire, Integrated Modular Avionics).
- Examine system integration, testing, certification, and lifecycle considerations from a systems engineering perspective.
- Apply functional hazard assessment and failure analysis techniques to aircraft systems.

Course Outcomes: At the end of the course students shall be able to

CO1	Describe the **architecture and operational principles** of primary and secondary aircraft systems.
CO2	Explain the **interdependencies and integration** between

	hydraulic, electrical, pneumatic, and flight control systems.
C03	Analyze **redundancy management and failure scenarios** in safety-critical systems.
C04	Identify the **key components and design requirements** for environmental control, fuel, ice protection, and landing gear systems.

Unit	Content	Credit	Weightage
I	**Fundamentals of Systems Engineering & Power Systems** (10 Hours) • **Systems Engineering Principles:** V-model, requirements development, verification & validation. ARP4754 overview. • **Aircraft Systems Overview:** Classification (primary vs. secondary, power-by-wire vs. power-by-fluid). • **Hydraulic Systems:** Principles, components (pumps, actuators, accumulators, valves). Fluid types. Typical system pressures (3000/5000 psi). Architecture (multiple independent systems). Power transfer units. • **Pneumatic Systems:** Bleed air sources (engines, APU), distribution, uses (engine start, pressurization, anti-ice). • **Electrical Systems:** Power generation (IDG, VSCF), distribution (AC/DC buses), batteries. Load management. Emergency power (RAT).	1	25%
II	**Flight Control & Avionics Systems** • **Flight Control Systems:** Primary (elevator, aileron, rudder) and secondary (flaps, slats, spoilers) controls. • **Actuation:** Hydraulic actuators (linear, rotary), servo valves. Mechanical backup systems. • **Fly-By-Wire (FBW):** Architecture, flight control computers, control laws (normal, alternate, direct). Airbus vs. Boeing philosophies. • **Avionics Architecture:** Federated vs. Integrated Modular Avionics (IMA). Data buses (ARINC 429, AFDX). • **Cockpit Systems:** Primary Flight Display (PFD), Navigation Display (ND), ECAM/EICAS.	1	25%

III	**Fuel, Environmental & Protection Systems** • **Fuel Systems:** Tank configurations, fuel transfer, jettison, gauging. Inerting systems. Engine feed. • **Environmental Control System (ECS):** Air cycle machine (ACM) and vapor cycle cooling. Cabin pressure control, temperature regulation, air distribution. Oxygen systems. • **Ice & Rain Protection:** Anti-icing (thermal, pneumatic) and de-icing (boots, electro-thermal) systems. Windshield heating and wipers. • **Fire Protection Systems:** Detection (smoke, heat, flame) and extinguishing (halon replacements) in engine, APU, and cargo bays.	1	25%
IV	**Landing Gear, Brakes & Advanced Topics** • **Landing Gear Systems:** Retraction/extension (mechanical, hydraulic), steering (nose wheel steering), shock absorption (oleo-pneumatic struts). • **Braking & Anti-Skid:** Hydraulic brake system, anti-skid (ABS) and auto-brake systems. • **Systems Integration & Safety:** Functional Hazard Assessment (FHA), Failure Modes and Effects Analysis (FMEA). Redundancy and separation requirements. • **Emerging Trends:** More Electric Aircraft (MEA) initiatives, prognostics and health management (PHM).	1	25%

Textbooks:

- Aircraft Systems: Mechanical, Electrical, and Avionics Subsystems Integration – Ian Moir and Allan Seabridge. (Wiley) *(Primary Text)*
- Introduction to Aircraft Flight Mechanics: Performance, Static Stability, Dynamic Stability, and Classical Feedback Control – Thomas R. Yechout, et al. (AIAA) – *For FBW background*.
- Civil Jet Aircraft Design – Lloyd R. Jenkinson, Paul Simpkin, Darren Rhodes. (Butterworth-Heinemann) – *For systems integration perspective*.
- Reference books:
- Design and Development of Aircraft Systems – Ian Moir and Allan Seabridge. (Wiley)
- Aircraft Design: A Systems Engineering Approach – Mohammad H. Sadraey. (Wiley)
- Avionics Navigation Systems – Myron Kayton and Walter R. Fried. (Wiley)
- SAE ARP4754A & ARP4761 – Guidelines for Development of Civil Aircraft and Systems / Safety Assessment.
- The Airliner Cabin Environment and the Health of Passengers and Crew – National Research Council. – *For ECS depth*.

Online Platforms:

- NPTEL Course: "Aircraft Systems and Instruments" by Prof. A.K. Ghosh (IIT Kanpur).

PRACTICAL LIST:

- Hydraulic System Schematic Analysis: Study of a transport aircraft hydraulic system schematic (e.g., Boeing 737 or A320). Identification of components, redundancy paths, and analysis of a failure scenario (e.g., loss of one hydraulic system).
- Fly-By-Wire Control Law Comparison: Simulation-based study (using basic sim software or diagrams) comparing the control law responses of a conventional aircraft vs. a FBW aircraft (e.g., pitch attitude hold, angle of attack protection).
- Fuel System Management Case Study: Analysis of fuel tank configuration and transfer sequences for a long-range aircraft. Calculation of CG shift during fuel burn and its system implications.
- Environmental Control System (ECS) Sizing Exercise: Simplified thermodynamic analysis of an Air Cycle Machine (ACM) pack to determine cooling capacity required for a given passenger load and external conditions.

SUBJECT CODE: BTAE703

SUBJECT NAME: SPACE TECHNOLOGY

Course Objectives:

- Introduce the fundamentals of astronautics, orbital mechanics, and space environment.
- Explain the design, subsystems, and mission planning for launch vehicles and spacecraft.
- Develop understanding of rocket propulsion, staging, and trajectory optimization.
- Examine spacecraft subsystems: power, thermal control, attitude determination and control (ADCS), communication, and structures.
- Explore applications of space technology: remote sensing, satellite communication, navigation, and interplanetary missions.
- Address contemporary topics: space debris, regulations, and emerging commercial space sector.

Course Outcomes: At the end of the course students shall be able to

CO1	Apply **orbital mechanics equations** to compute basic orbital parameters and maneuvers.
CO2	Describe the **working principles and performance parameters** of chemical rocket propulsion systems.
C03	Explain the **function and design considerations** of major spacecraft subsystems.
C04	Analyze **mission profiles** for launch vehicles and differentiate between satellite orbits (LEO, MEO, GEO, Polar).

Unit	Content	Credit	Weightage
I	**Orbital Mechanics & Space Environment** • **Introduction:** Brief history of astronautics. Overview of space missions (robotic, human). • **Two-Body Problem:** Kepler's Laws, Newton's Law of Universal Gravitation. Orbit equation, orbital elements (a, e, i, Ω, ω, ν).	1	25%

	• **Orbit Types:** Circular, elliptical, parabolic, hyperbolic. Earth orbits: LEO, MEO, GEO, Sun-synchronous, Molniya. • **Orbital Maneuvers:** Hohmann transfer, plane change, orbit phasing. • **Space Environment:** Vacuum, microgravity, radiation belts (Van Allen), solar flux, space debris.		
II	**Rocket Propulsion & Launch Vehicle Design** • **Rocket Fundamentals:** Thrust equation, specific impulse (Isp), total impulse. Rocket equation (Tsiolkovsky). • **Chemical Propulsion:** Propellant types (solid, liquid, hybrid). Liquid engine cycles (pressure-fed, gas generator, staged combustion). Nozzle expansion. • **Launch Vehicle Design:** Staging theory and optimization. Structural considerations, payload fairing. • **Launch Trajectories:** Gravity turn, pitch-over maneuver. Launch windows. • **Introduction to Electric Propulsion** (Hall effect, ion thrusters).	1	25%
III	**Spacecraft Systems Engineering** • **Spacecraft Subsystems Overview:** System-level design and integration. • **Attitude Determination and Control System (ADCS):** Attitude parameters, stabilization methods (spin, 3-axis). Sensors (sun, star, horizon, gyro) and actuators (thrusters, reaction wheels, magnetorquers). • **Power Systems:** Solar arrays, batteries (Li-ion, Ni-Cd), power conditioning. • **Thermal Control:** Passive (coatings, multilayer insulation) and active (heaters, louvers, fluid loops) methods. • **Telemetry, Tracking & Command (TT&C):** Communication links, transponders, antennas.	1	25%
IV	**Satellite Applications & Advanced Topics** • **Satellite Applications:**	1	25%

	○ **Remote Sensing:** Optical and SAR payloads, spectral bands, resolution (spatial, spectral, temporal). ○ **Communication Satellites:** Transponders, frequency bands (C, Ku, Ka), link budget basics. ○ **Navigation Satellites:** GNSS principles (GPS, Galileo), trilateration. • **Spacecraft Structures & Materials:** Launch loads, typical configurations (bus, payload), lightweight materials. • **Current Topics:** Small satellites (CubeSats), reusable launch vehicles (RLVs), interplanetary mission profiles, space debris mitigation.		

Textbooks:

- Fundamentals of Astrodynamics – Roger R. Bate, Donald D. Mueller, Jerry E. White. (Dover Publications) *(Primary Text for Orbital Mechanics)*
- Rocket Propulsion Elements – George P. Sutton, Oscar Biblarz. (Wiley) *(Primary Text for Propulsion)*
- Spacecraft Systems Engineering – Peter Fortescue, Graham Swinerd, John Stark (Editors). (Wiley)

Reference Books:

- Understanding Space: An Introduction to Astronautics – Jerry Jon Sellers, et al. (McGraw-Hill)
- Satellite Communications – Timothy Pratt, Charles Bostian, Jeremy Allnutt. (Wiley)
- Remote Sensing of the Environment: An Earth Resource Perspective – John R. Jensen. (Pearson)
- Space Mission Analysis and Design (SMAD) – James R. Wertz, David F. Everett, Jeffery J. Puschell. (Microcosm Press/Springer)
- Introduction to Space Dynamics – William Tyrrell Thomson. (Dover)

Online Platforms:

- NPTEL Course: "Space Flight Mechanics" by Prof. C. Venkatesan (IIT Kanpur).

PRACTICAL LIST:

- **Orbital Parameters & Maneuver Calculation:** Given initial orbital elements, compute the delta-v required for a specified Hohmann transfer or simple plane change using MATLAB/Python or analytical methods.
- **Rocket Performance Analysis:** Using the ideal rocket equation, calculate the required propellant mass for a given payload mass, delta-v, and specific impulse. Analyze the effect of staging.
- **Satellite Link Budget Preliminary Analysis:** Perform a simplified downlink budget calculation for a communication satellite, estimating received power based on transmitted power, frequency, distance, and antenna gains.
- **Mission Profile & Subsystem Sizing (Case Study):** For a given Earth observation CubeSat mission (e.g., 3U CubeSat in 500 km SSO), perform preliminary sizing/power budget for solar array and battery, and select appropriate ADCS sensors and actuators from vendor datasheets.

SUBJECT CODE: BTAE704

SUBJECT NAME: ADAPTIVE MANUFACTURING LAB

Course Objectives:

- Introduce digital manufacturing technologies (Additive Manufacturing, CNC machining) and their role in aerospace production.
- Develop practical skills in CAD-to-part workflows, including design optimization, toolpath generation, and post-processing.
- Demonstrate design-for-manufacturing (DFM) principles specific to lightweight, high-strength aerospace components.
- Impart knowledge of material-specific processing, parameter optimization, and quality inspection for additive and subtractive methods.
- Foster understanding of hybrid and adaptive manufacturing strategies for prototyping, tooling, and repair.
- Prepare students for industry 4.0 trends in aerospace manufacturing, including digital twins and rapid prototyping.

Course Outcomes: At the end of the course students shall be able to

CO1	Operate and program **3D printers (FDM, SLA)** and **CNC milling machines** for basic aerospace components.
CO2	Apply **design-for-additive-manufacturing (DfAM)** principles to create lightweight, topology-optimized structures.
C03	Generate and simulate **G-code toolpaths** using CAM software for subtractive manufacturing.
C04	Select appropriate **manufacturing parameters** (layer height, infill, feed rate, spindle speed) based on material and application.

Practical List:

Module 1: Introduction to Additive Manufacturing (FDM/SLA)

- Lab 1: FDM Aerospace Bracket – Design & Fabrication
  - Objective: Design a lightweight aircraft bracket using CAD. Apply basic DfAM principles (minimize supports, optimize orientation). Slice using Ultimaker Cura/Fusion 360.
  - Tasks:
    1. CAD modeling of a mounting bracket with weight-saving features.
    2. Slicer parameter selection (layer height 0.2mm, 30% gyroid infill, PLA/ABS).
    3. 3D printing and post-processing (support removal).
    4. Dimensional verification using calipers.
- Lab 2: Stereolithography (SLA) for Complex Geometries
- Objective: Fabricate a high-resolution aerodynamic surface (e.g., wingtip, vortex generator) using SLA.
- Tasks:
  - Import an airfoil STL file or design a small aerodynamic component.
  - Prepare build file in Chitubox/PrusaSlicer (orientation, supports).
  - 3D print using resin (standard/tough).
  - Post-process: washing, UV curing, and surface finish evaluation.

Module 2: CNC Machining Fundamentals

- Lab 3: 2.5-Axis CNC Milling of an Aircraft Spacer/Shim

  - Objective: Machine an aluminum alloy (6061) spacer from a stock block using a 3-axis CNC mill.
  - Tasks:
    1. CAD model of a spacer with lightening holes.
    2. CAM programming in Fusion 360 (facing, pocketing, contouring operations).
    3. Toolpath simulation and G-code generation.
    4. Setup: workpiece fixturing, tool length offset, zeroing.
    5. Machining and inspection of critical dimensions.
- Lab 4: 3-Axis CNC Machining of a Wing Rib Prototype
  - Objective: Machine a simplified aluminum wing rib with contour profiles and lightening holes.
  - Tasks:
    1. Import rib CAD model (IGES/STEP).
    2. CAM setup: roughing (adaptive clearing) and finishing (parallel) strategies.
    3. Selection of cutting tools (end mills), feeds/speeds calculation.
    4. Machine setup and safe operation.
    5. Post-machining deburring and surface roughness measurement.

Module 3: Hybrid Manufacturing & Repair

- Lab 5: Additive Repair of a Damaged Bracket
-
  - Objective: Demonstrate additive repair by depositing material on a deliberately damaged aluminum bracket.
  - Tasks:
    1. Scan damaged bracket (using photogrammetry or manual measurement).
    2. CAD modeling of repair volume.
    3. Use FDM printer with high-temp nozzle to deposit carbon-fiber reinforced filament onto preheated substrate (simulating directed energy deposition principle).
    4. Post-process machining of repaired area to net shape.
- Lab 6: Composite Layup Tool Fabrication via Additive Manufacturing
  - Objective: Design and 3D print (large-format FDM) a male/female mold for a carbon fiber composite layup.
-
  - Tasks:
    1. Design a curved tool surface (e.g., for a small UAV wing skin).
    2. Print with high-temperature material (e.g., ABS, ASA) on a large-format printer.
    3. Post-process: surface sealing (epoxy coating), polishing.
    4. Demonstration: dry layup of carbon fiber on the tool (optional infusion/vacuum bagging demo).

Module 4: Inspection, Metrology & Digital Workflow

- Lab 7: Reverse Engineering & Digital Twin Comparison
  - Objective: Scan a manufactured part and compare it to its original CAD model.
  - Tasks:
-
  -
    1. 3D scan a machined/printed part using a structured light scanner or photogrammetry app (Polycam/Scaniverse).

2. Import scan data (point cloud) into inspection software (CloudCompare/MeshLab).
3. Perform 3D deviation analysis (color map) between scan and original CAD.
4. Identify critical dimensional errors.

- Lab 8: Topology Optimization & Lightweighting
  - Objective: Redesign a bracket for weight reduction using topology optimization and manufacture it.
  - Tasks:
    1. Define design space, constraints, and loads (e.g., 500N static load) in Fusion 360/ANSYS.
    2. Run topology optimization (maximize stiffness, 50% mass target).
- Post-process the optimized shape into a manufacturable design.
- Manufacture using either FDM (nylon-carbon fiber) or CNC (aluminum).
- Compare weight and stiffness with original design.

SEMESTER-VIII

SUBJECT CODE: BTAE801

SUBJECT NAME: AIROSPACE MANUFACTURING

Course Objectives:

- Introduce advanced, aerospace-specific manufacturing processes for metallic, composite, and polymeric materials.
- Develop understanding of airworthiness certification requirements (FAA/EASA Part 21, AS/EN9100) in manufacturing.
- Impart knowledge of specialized processes: automated fiber placement (AFP), friction stir welding (FSW), electron beam welding (EBW), precision casting, and chemical milling.
- Examine digital thread, model-based enterprise (MBE), and digital twin applications in aerospace production.
- Analyze lean manufacturing, cost modeling, and supply chain strategies unique to the aerospace industry.

Course Outcomes: At the end of the course students shall be able to

CO1	Select appropriate **manufacturing processes** based on aerospace material properties (Al, Ti, composites) and component function.
CO2	Explain **certification and quality standards** (NADCAP, AS9100) governing aerospace production.
C03	Describe the **principles, advantages, and limitations** of advanced processes like AFP, FSW, and EBW.
C04	Apply **digital manufacturing concepts** (MBE, digital thread) to an aerospace production workflow.

Unit	Content	Credit	Weightage
I	**Aerospace Manufacturing Fundamentals & Certification** • **Aerospace Manufacturing Landscape:** Tiered supply chain (OEM, Tier 1-3), Make vs. Buy strategies. • **Materials & Processes Selection:** Manufacturing considerations for aerospace alloys (Al 7xxx, Ti-6Al-4V), composites (CFRP, GFRP), and superalloys (Inconel). • **Quality Management & Certification:** AS/EN9100 Quality Management System (QMS). FAA/EASA Part 21 Production Organization Approval (POA). NADCAP special process accreditation.	1	25%

<table>
<tr><td></td><td>Cost Drivers & Lean Principles: Cost of poor quality (COPQ), value stream mapping for aerospace assembly.</td><td></td><td></td></tr>
<tr><td>II</td><td>Advanced Metallic Component Manufacturing
Precision Machining: High-speed machining (HSM) of Al and Ti. Cryogenic machining. Dynamic milling strategies.
Joining Technologies:
Friction Stir Welding (FSW): Process mechanics, tool design, applications (aircraft skins, fuel tanks).
Electron Beam & Laser Beam Welding: Vacuum chamber operations, joint configurations for engines.
Forming & Casting: Superplastic forming (SPF) of Ti. Investment casting of turbine blades (wax pattern, ceramic shell).
Surface Treatments & Coatings: Anodizing, alodining, thermal spray (TPS), peening.</td><td>1</td><td>25%</td></tr>
<tr><td>III</td><td>Composite Manufacturing & Automation
Composite Fundamentals: Prepreg handling, autoclave cure cycle (vacuum, pressure, temperature).
Automated Layup: Automated Tape Laying (ATL) and Automated Fiber Placement (AFP). Programming and path generation.
Out-of-Autoclave (OOA) Processes: Vacuum Assisted Resin Transfer Molding (VARTM), resin infusion.
Repair & Bonding: Composite scarf repair, cocuring, secondary bonding.
Additive Manufacturing for Aerospace: DMLS (Direct Metal Laser Sintering) for engine parts, FAA certification path for AM parts.</td><td>1</td><td>25%</td></tr>
<tr><td>IV</td><td>Digital Manufacturing, Assembly & Inspection
Digital Thread & Model-Based Enterprise (MBE): 3D Model-Based Definition (MBD), PMI (Product Manufacturing Information).
Aircraft Assembly: Jigs & fixtures, deterministic assembly, digital shimming. Major component join (wing-fuselage).</td><td>1</td><td>25%</td></tr>
</table>

	• **Metrology & NDT:** Coordinate Measuring Machines (CMM), laser trackers. Non-Destructive Testing (NDT): Ultrasonic testing (UT), eddy current, thermography for composites. • **Emerging Trends:** Robotics in assembly (cobots), augmented reality (AR) for wiring harness installation, sustainable/green manufacturing.		

Textbooks:

- Aircraft Manufacturing and Assembly – Daniel P. Raymer and Y. Srinivasa. (AIAA Education Series) *(Primary Text)*
- Composites Manufacturing: Materials, Product, and Process Engineering – Sanjay Mazumdar. (CRC Press)
- Fundamentals of Modern Manufacturing: Materials, Processes, and Systems – Mikell P. Groover. (Wiley) – *For core principles*.

Reference Books:

- Friction Stir Welding: From Basics to Applications – Daniela Lohwasser and Zhili Feng. (Woodhead Publishing)
- The Airframe Manufacturing Handbook – Michael J. Kroes, William A. Watkins, and Frank Delp. (McGraw-Hill)
- Additive Manufacturing for the Aerospace Industry – Francis H. Froes and Rodney Boyer. (Elsevier)
- AS9100D: Quality Management Systems - Requirements for Aviation, Space, and Defense Organizations – SAE International.
- Automated Composites Manufacturing – Arnt Offringa. (SAMPLE Publishing)

Online Platforms:

- SAE International – For aerospace standards (AS, AMS).
- Nadcap – Checklists for special process accreditation.
- MIT OpenCourseWare: "Airplane Manufacturing" or related courses.
- GE Aerospace Additive Manufacturing and Airbus SAF (Sustainable Aerospace Factory) online resources**.**

PRACTICAL LIST:

1. Composite Panel Fabrication & Ultrasonic Inspection
    - Objective: Manufacture a carbon fiber laminate and inspect for defects.
    - Tasks:
        1. Hand layup of a 6-ply carbon fiber/epoxy prepreg panel.
        2. Vacuum bagging and curing in an oven/autoclave simulator.
        3. Ultrasonic A-scan inspection of the panel to detect simulated delaminations (Teflon inserts).
        4. Analysis of ultrasonic signal data.
2. Friction Stir Welding Demonstration & Macrostructural Analysis
    - Objective: Understand FSW process parameters and joint characteristics.
    - Tasks:

1. Witness an FSW demonstration on aluminum plates (or operate a benchtop system).
2. Variation of parameters (RPM, traverse speed) on different samples.
3. Sectioning, mounting, polishing, and etching of weld cross-sections.
4. Macroscopic examination of weld nugget, TMAZ, and HAZ.

3. Reverse Engineering & CMM Inspection of an Aerospace Bracket
   - Objective: Generate a digital model from a physical part and verify dimensions.
   - Tasks:
     1. 3D scan a complex aircraft bracket using a structured light scanner.
     2. Process point cloud to create a CAD model (reverse engineering).
     3. Program a CMM (or use a portable arm) to inspect critical features of the original bracket.
     4. Generate an inspection report with deviations from nominal dimensions.
4. Model-Based Definition (MBD) & Toolpath Generation for a Rib Component
   - Objective: Apply digital manufacturing workflow from 3D model to machine instructions.
   - Tasks:
     1. Assign PMI (dimensions, tolerances, notes) to a 3D wing rib model in CAD (Creo/SolidWorks).
     2. Import the MBD model into CAM software (Mastercam/Fusion 360).
     3. Generate and simulate CNC toolpaths for machining the rib from aluminum stock.
     4. Post-process to generate G-code (for demonstration, not necessarily cutting).

SUBJECT CODE: BTAE802

SUBJECT NAME: AIROSPACE REGULATIONS AND SAFETY

Course Objectives:

- Provide a comprehensive understanding of the national and international regulatory framework governing civil aviation (ICAO, FAA, EASA, DGCA).
- Explain the certification processes for aircraft, components, and organizations (type certification, production certification, airworthiness certification).
- Introduce safety management systems (SMS) and fundamental aircraft accident investigation methodologies.
- Examine airspace classification, air traffic management (ATM), and operational regulations for flight crews and operators.
- Analyze human factors, maintenance regulations, and cybersecurity considerations in aviation safety.
- Discuss emerging regulatory challenges for new technologies (UAS, eVTOL, commercial space).

Course Outcomes: At the end of the course students shall be able to

CO1	Navigate and interpret key **aviation regulations** (FAR/CS, ICAO Annexes, CAR).
CO2	Describe the **stages and requirements** for aircraft type certification and continuing airworthiness.
C03	Apply **safety management principles** and analyze accidents using investigation models (SHELL, Reason's Swiss Cheese).
C04	Explain **airspace structure, ATC procedures, and operational rules** for different flight categories.

<table>
<tr><th>Unit</th><th>Content</th><th>Credit</th><th>Weightage</th></tr>
<tr><td>I</td><td>International & National Regulatory Framework

International Civil Aviation: Chicago Convention (1944), ICAO structure and functions. ICAO Annexes (focus on Annexes 1, 6, 8, 19).
Comparative Regulatory Systems:

FAA (USA): Title 14 CFR (Parts 21, 23, 25, 33, 35, 91, 121, 135).
EASA (EU): Basic Regulation, Certification Specifications (CS).
DGCA (India): Civil Aviation Requirements (CAR), Aircraft Rules (1937).

Bilateral Agreements: BASA (Bilateral Aviation Safety Agreement), TIP (Technical Implementation Procedures).
Certification Basis & Type Certification: Type Certification Process, Certification Plan, Means of Compliance.
</td><td>1</td><td>25%</td></tr>
<tr><td>II</td><td>Aircraft Certification & Continuing Airworthiness

Type Certification: Stages (Concept, Requirements, Compliance, Post-Certification). Type Certificate Data Sheet (TCDS).
Design & Production Approval:

Part 21: Type, Production, and Airworthiness Certificates.
Part 145: Approved Maintenance Organizations.
Part M: Continuing Airworthiness Management.

Airworthiness Standards:

CS/FAR Part 23/25: Normal/Transport Category Airplanes.
CS/FAR Part 27/29: Normal/Transport Category Rotorcraft.
Special Conditions for novel technologies.

Airworthiness Directives (ADs): Issuance, classification, and compliance.
</td><td>1</td><td>25%</td></tr>
<tr><td>III</td><td>Safety Management & Accident Investigation</td><td>1</td><td>25%</td></tr>
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	• **Safety Management Systems (SMS):** ICAO Annex 19. Four components (Safety Policy, Risk Management, Safety Assurance, Safety Promotion). • **Accident & Incident Investigation:** ICAO Annex 13. Investigation bodies (AAIB, NTSB). Investigation process and final report. • **Human Factors in Aviation:** SHELL Model (Software, Hardware, Environment, Liveware). Error models (Skill, Rule, Knowledge-based). Crew Resource Management (CRM). • **Risk Assessment Tools:** Bow-Tie analysis, Fault Tree Analysis (FTA). • **Safety Culture:** Just Culture vs. Blame Culture. Reporting systems (ASRS, MOR).		

IV	**Operations, Airspace & Future Challenges**
	
	• **Operational Regulations:**
	  ○ **Part 91/135/121:** General, Commuter, and Air Carrier Operations.
	  ○ Flight & Duty Time Limitations (FTL).
	• **Airspace & Air Traffic Management (ATM):** ICAO Airspace Classification (Class A-G). CNS/ATM (Communication, Navigation, Surveillance). Performance-Based Navigation (PBN).
	• **Regulation of New Entrants:**
	  ○ **Unmanned Aircraft Systems (UAS):** Part 107, Specific Category, BVLOS regulations.
	  ○ **Advanced Air Mobility (AAM):** eVTOL certification basis (SC-VTOL), vertiport standards.
	  ○ **Commercial Space:** Licensing of launch and re-entry (FAA/AST, IN-SPACe).
	• **Cybersecurity & Environmental Regulations:** Airworthiness security (ED-202A/DO-326A).
		1	25%

Textbooks:

- Introduction to Aviation Regulations and Safety – J. P. Hanlon. (McGraw-Hill) *(Primary Text)*
- Aircraft Safety: Accident Investigations, Analyses, & Applications – Shari Stamford Krause. (McGraw-Hill)
- Federal Aviation Regulations (FAR) / EASA Easy Access Rules: *Official regulatory texts (digital).*

Reference Books:

- The International Law on Civil Aviation – Michael Milde. (Eleven International Publishing)
- Human Factors in Aviation – Eduardo Salas and Dan Maurino. (Academic Press)
- Safety Management Systems in Aviation – Alan J. Stolzer, Carl D. Halford, John J. Goglia. (Ashgate)
- DO-178C / ED-12C: Software Considerations in Airborne Systems and Equipment Certification – RTCA/EUROCAE. *(For software certification)*
- **Practical Guide to Airline Safety Management Systems – Tony Licu. (ICAO)**

Online Platforms:

- ICAO Document Sales Platform & iSTARS: For Annexes and documents.
- FAA Regulatory & Guidance Library (RGL) & EASA Regulations: Official regulatory portals.
- DGCA India Website: For CARs and notifications.
- RTCA & EUROCAE: For technical performance standards (DO/ED documents).

SUBJECT CODE: BTAE803

SUBJECT NAME: INTRODUCTION TO ROBOTICS

Course Objectives:

- Introduce the fundamental principles, components, and configurations of robotic systems.
- Develop kinematic modeling and analysis skills for robotic manipulators relevant to aerospace automation.
- Impart knowledge of actuators, sensors, and control systems used in industrial and mobile robotics.
- Provide programming and simulation experience with robotic arms for aerospace applications (drilling, painting, inspection).
- Explore emerging robotic applications in aerospace: UAVs, collaborative robots (cobots) in assembly, and mobile robots for maintenance.
- Bridge theoretical robotics with practical, hands-on implementation for aeronautical engineering contexts.

Course Outcomes: At the end of the course students shall be able to

CO1	Describe the **basic components, configurations, and specifications** of robotic systems.
CO2	Perform **forward and inverse kinematic analysis** for simple serial manipulators.
C03	Program and simulate **basic robotic tasks** (pick-and-place, trajectory following) using simulation software.
C04	Interface **sensors (vision, force) and end-effectors** with robotic systems for specific applications.

Unit	Content	Credit	Weightage
I	**Fundamentals of Robotics & Kinematics** • **Introduction:** Definition, history, and classification of robots. Robot anatomy: links, joints, end-effectors. • **Aerospace Robotics Applications:** Drilling, riveting, painting, inspection, composite layup, warehousing.	1	25%

	Spatial Descriptions & Transformations: Position and orientation representation. Rotation matrices. Homogeneous transformations. **Forward Kinematics:** Denavit-Hartenberg (D-H) parameters and convention. Derivation of forward kinematics for 3-DOF and 4-DOF manipulators. **Inverse Kinematics:** Concepts and challenges. Geometric and algebraic solutions for simple manipulators (2R planar, SCARA-type).		
II	**Dynamics, Trajectory Planning & Actuation** **Jacobians:** Velocity kinematics, mapping joint velocities to end-effector velocity. Concept of singularities. **Dynamics Overview:** Lagrange-Euler formulation (concept only). Inertia, Coriolis, and centrifugal forces. **Trajectory Planning:** Joint space vs. Cartesian space planning. Point-to-point and continuous path motion. Cubic polynomial trajectory generation. **Actuators & Drive Systems:** Electric actuators (DC servo, stepper), hydraulic, and pneumatic. Gears and transmission. **Sensors:** Position encoders, force/torque sensors, and vision systems (introductory).	1	25%
III	**Robot Control & Programming** **Control Systems Overview:** Open-loop vs. closed-loop control. **Joint Level Control:** Independent joint PID control. **Robot Programming:** Introduction to programming methods (lead-through, teach pendant, offline). Common robot programming languages (RAPID, KRL, URScript). **Introduction to ROS (Robot Operating System):** Core concepts (nodes, topics, services). Visualization with RViz. **Simulation Software:** Introduction to using simulation environments (e.g., CoppeliaSim (V-REP), RoboDK, MATLAB Robotics Toolbox).	1	25%
IV	**Aerospace Applications & Advanced Topics**	1	25%

	• **Industrial Robotics in Aerospace:** Case studies: robotic drilling for aircraft fuselage, automated fiber placement (AFP) machines as specialized robots. • **Collaborative Robots (Cobots):** Safety standards (ISO/TS 15066), applications in aircraft assembly. • **Mobile Robotics:** Unmanned Ground Vehicles (UGVs) for aircraft inspection and cargo handling. Integration of UAVs as aerial robots. • **Robot Vision & Force Control:** Simple vision-guided pick-and-place. Introduction to force-controlled robotic grinding or deburring. • **Future Trends:** Swarm robotics, AI in robotics, digital twin for robotic work cells.		

Textbooks:

- Introduction to Robotics: Mechanics and Control – John J. Craig. (Pearson) *(Primary Text)*
- Robotics, Vision and Control: Fundamental Algorithms in MATLAB – Peter Corke. (Springer) *Excellent for computation & simulation*
- A Mathematical Introduction to Robotic Manipulation – Richard M. Murray, Zexiang Li, S. Shankar Sastry. (CRC Press)

Reference Books:

- Handbook of Robotics – Bruno Siciliano, Oussama Khatib (Eds.). (Springer)
- Robot Modeling and Control – Mark W. Spong, Seth Hutchinson, M. Vidyasagar. (Wiley)
- Industrial Robotics: Technology, Programming and Applications – Mikell P. Groover, Mitchell Weiss, Roger N. Nagel, Nicholas G. Odrey. (McGraw-Hill)
- ROS Robotics By Example – Carol Fairchild, Thomas L. Harman. (Packt)

Online Platforms:

- NPTEL Course: "Introduction to Robotics" by Prof. S. K. Saha (IIT Delhi).
- Stanford University Robotics (CS223A) Online Lectures.
- Coursera: "Robotics Specialization" (University of Pennsylvania).

PRACTICAL LIST:

- **Forward & Inverse Kinematics Simulation**
  1. **Objective:** Model a 3-DOF or 4-DOF robotic arm and validate its kinematics.
  2. **Tasks:**
     1. Assign D-H parameters to a given robot model in simulation software.
     2. Write a script/function to compute the forward kinematics.
     3. For a given end-effector position, compute the inverse kinematics (geometric method).
     4. Animate the robot moving between computed joint angles.
- **Robotic Trajectory Planning and Programming**
  1. **Objective:** Program a robot to perform a pick-and-place operation relevant to aerospace (e.g., moving a fastener from a tray to a target location).
  2. **Tasks:**

1. Generate a smooth cubic polynomial trajectory for each joint from "pick" to "place" configuration.
2. Program the trajectory on a physical/simulated robot using teach pendant or script.
3. Execute the program and analyze the motion smoothness and accuracy.

- **Robot Vision for Part Identification**
  1. **Objective:** Use a camera to identify and locate different aircraft parts (e.g., rivets, brackets) for robotic handling.
  2. **Tasks:**
     1. Set up a simulated or physical overhead camera view of a workspace with different parts.
     2. Use image processing (color/blob detection, template matching) to identify part type and (x, y) location.
     3. Send the part coordinates to the robot controller to guide the end-effector for pickup.
- **Aerospace Case Study Simulation: Robotic Drilling**
- **Objective:** Simulate a robotic drilling task on an aircraft panel.
- **Tasks:**
  1. Model a simple aircraft panel and a drilling end-effector in simulation software.
  2. Program the robot to follow a predefined pattern of drill holes.
  3. Implement a simulated force sensor to detect contact with the panel.
  4. Analyze the cycle time and accuracy of the simulated operation.