MK UNIVERSITY

PATAN, GUJARAT

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MK University, Patan
Faculty of Engineering Technology,
Department of Aeronautical Engineering

M. TECH (AERONAUTICAL ENGINEERING) SEM-I

SR NO.	COURSE TYPE	COURSE CODE	COURSE NAME	LECTURE (HRS.)/WEEK	PRACTICAL (HRS.)/WEEK	CREDITS	EXAMINATION		TOTAL MARKS
							INTERNAL	EXTERNAL	
1	MAJOR	MTAE101	ADVANCED MATHEMATICS FOR ENGINEERS	4	0	4	40	60	100
2	MAJOR	MTAE102	ADVANCED AERODYNAMICS	4	2	6	90	60	150
3	MAJOR	MTAE103	AIRCRAFT STRUCTURES & AEROELASTICITY	4	2	6	90	60	150
4	MINOR	MTAE104	RESEARCH METHDOLOGY & TECHNICAL COMMUNICATION	4	0	4	40	60	100
5	SEC	MTAE105	ENTERPRENURSHIP DEVELOPMENT	4	0	4	40	60	100
TOTAL				20	4	24	300	300	600

M. TECH (AERONAUTICAL ENGINEERING) SEM-II

SR NO.	COURSE TYPE	COURSE CODE	COURSE NAME	LECTURE (HRS.)/WEEK	PRACTICAL (HRS.)/WEEK	CREDITS	EXAMINATION		TOTAL MARKS
							INTERNAL	EXTERNAL	
1	MAJOR	MTAE201	ADVANCED AEROSPACE MATERIALS	4	0	4	40	60	100
2	MAJOR	MTAE202	FLIGHT DYNAMICS & CONTROL	4	2	6	90	60	150
3	MAJOR	MTAE203	SPACE MECHANICS & SATELLITE TECHNOLOGY	4	2	6	90	60	150
4	MINOR	MTAE204	AEROACOUSTICS	4	2	6	90	60	150
5	VAC	MTAE205	BUSINESS COMMUNICATION-I	2	0	2	0	50	50
TOTAL				18	6	24	310	290	600

M. TECH (AERONAUTICAL ENGINEERING) SEM-III

SR NO.	COURSE TYPE	COURSE CODE	COURSE NAME	LECTURE (HRS.)/ WEEK	PRACTICAL (HRS.)/ WEEK	CREDITS	EXAMINATION		TOTAL MARKS
							INTERNAL	EXTERNAL	
1	MAJOR	MTAE301	TURBULENCE MODELING	4	2	6	90	60	150
2	MAJOR	MTAE302	HELICOPTER AERODYNAMICS	4	2	6	90	60	150
3	MINOR	MTAE303	MOOC/SWAYAM COURSE	3	0	3	100	00	100
4	VAC	MTAE304	DISSERTATION PHASE-I	0	8	8	100	100	200
TOTAL				11	12	23	380	220	600

M. TECH (AERONAUTICAL ENGINEERING) SEM-IV

SR NO.	COURSE TYPE	COURSE CODE	COURSE NAME	LECTURE (HRS.)/ WEEK	PRACTICAL (HRS.)/ WEEK	CREDITS	EXAMINATION		TOTAL MARKS
							INTERNAL	EXTERNAL	
1	MAJOR	MTAE401	INDUSTRY SEMINARS/WORKSHOPS/INTERNSHIP	0	2	2	50	00	50
2	MINOR	MTAE402	COMPREHENSIVE VIVA VOCE	0	2	2	50	00	50
3	MAJOR	MTAE403	DISEERTATION PHASE-II	0	16	16	200	200	400
4	VAC	MTAE404	BUSINESS COMMUNICATION-II	2	0	2	00	50	50
TOTAL				2	20	22	300	250	550

SEMESTER-I

SUBJECT CODE: MTAE101

SUBJECT NAME: ADVANCED MATHEMATICS FOR ENGINEERS

Course Objectives:

- To provide a rigorous mathematical foundation for advanced engineering modeling and analysis.
- To bridge theoretical mathematics with practical engineering applications.
- To develop problem-solving skills using analytical and computational tools.
- To prepare students for research and development in engineering domains requiring mathematical sophistication.

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

CO1	Formulate and solve engineering problems using advanced techniques in linear algebra and tensor analysis.
CO2	Apply partial differential equations (PDEs) and transform methods to model dynamical systems and boundary value problems.
CO3	Use variational calculus and optimization methods for engineering design and control problems.
CO4	Analyze stochastic systems and uncertainty propagation using probability theory and statistical methods.

Unit	Content	Credit	Weightage
I	**Advanced Linear Algebra & Tensors for Engineers** ○ Review of vector spaces, eigenvalues, SVD, Jordan form ○ Matrix decompositions (LU, QR, Cholesky, Schur) ○ Tensor algebra: notation, operations, invariants ○ Tensor applications: stress-strain, inertia, constitutive models ○ Numerical linear algebra (conditioning, iterative solvers) • **Applications:** Structural analysis, continuum mechanics, control systems, data compression.	1	25%
II	**Partial Differential Equations & Transform Methods** ○ Classification of PDEs (elliptic, parabolic, hyperbolic) ○ Separation of variables, eigenfunction expansions ○ Green’s functions for ODEs and PDEs ○ Integral transforms (Fourier, Laplace, Hankel) for PDEs ○ Introduction to finite element and finite volume concepts	1	25%

	• **Applications:** Heat transfer, wave propagation, fluid dynamics, signal processing.		
III	**Calculus of Variations & Optimization** ○ Functional derivatives, Euler–Lagrange equation ○ Constraints (Lagrange multipliers, isoperimetric problems) ○ Direct methods (Ritz, Galerkin) ○ Optimal control theory (Pontryagin's principle, Hamiltonian formulation) ○ Convex optimization basics (gradient descent, KKT conditions) • **Applications:** Optimal design, trajectory optimization, energy minimization, control systems.	1	25%
IV	**Stochastic Processes & Uncertainty Quantification** ○ Probability spaces, random variables, distributions ○ Stochastic processes (Brownian motion, Poisson process, Markov chains) ○ Itô calculus basics (stochastic differential equations) ○ Uncertainty quantification (Monte Carlo, polynomial chaos, sensitivity analysis) ○ Statistical estimation and regression for engineering data • **Applications:** Risk analysis, reliability engineering, random vibrations, financial engineering, signal noise modelling	1	25%

TEXT BOOKS:

- Kreyszig, E. – *Advanced Engineering Mathematics* (10th ed.) – Wiley.
- Strang, G. – *Linear Algebra and Its Applications* (5th ed.) – Cengage.
- Arfken, G.B., Weber, H.J., Harris, F.E. – *Mathematical Methods for Physicists* (7th ed.) – Academic Press.
- J.N. Reddy – *Applied Functional Analysis and Variational Methods in Engineering* – McGraw-Hill.
- Papoulis, A., & Pillai, S.U. – *Probability, Random Variables and Stochastic Processes* (4th ed.) – McGraw-Hill.

REFERENCE BOOKS:

- Riley, K.F., Hobson, M.P., Bence, S.J. – *Mathematical Methods for Physics and Engineering* (3rd ed.) – Cambridge.
- Gelfand, I.M., & Fomin, S.V. – *Calculus of Variations* – Dover.
- Oksendal, B. – *Stochastic Differential Equations: An Introduction with Applications* (6th ed.) – Springer.
- Holmes, M.H. – *Introduction to Numerical Methods in Differential Equations* – Springer.
- Gould, P. – *Introduction to Linear Elasticity* (for tensor applications) – Springer.

ONLINE RESOURCES:

- Coursera:
  - *Mathematics for Engineers Specialization* (The Hong Kong University of Science and Technology)
  - *Data Science Math Skills* (Duke University)

SUBJECT CODE: MTAE102

SUBJECT NAME: ADVANCED AERODYNAMICS

Course Objectives:

- To provide advanced mathematical foundations for analyzing inviscid and viscous flows
- To understand high-speed aerodynamics including transonic, supersonic, and hypersonic regimes
- To analyze three-dimensional flows, wing theory, and boundary layer phenomena
- To introduce computational aerodynamics methods and turbulence modeling
- To explore specialized topics: unsteady aerodynamics, rotor aerodynamics, and aeroelasticity basics

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

CO1	**Mathematically formulate** and solve inviscid flow problems using potential flow theory
CO2	**Analyze compressible flows** across different Mach regimes with appropriate approximations
CO3	**Apply boundary layer theory** to predict flow separation and skin friction
CO4	**Implement computational methods** for solving aerodynamic problems

Unit	Content	Credit	Weightage
I	**Advanced Inviscid Flows & Potential Theory** **Topics:** • Mathematical foundations: Complex variables, conformal mapping • Advanced potential flow theory: Source, sink, doublet, vortex panels • Air foil theory: Thin air foil theory revisited, camber effects • Finite wing theory: Prandtl's lifting line theory, induced drag • Three-dimensional flows: Slender body theory, wing-body interactions • **Practical:** Panel method coding for 2D air foils, wing loading calculations	1	25%
II	**Compressible Aerodynamics** **Topics:** • Review of normal and oblique shocks, expansion waves • Transonic flow: Critical Mach number, area rule, supercritical airfoils • Supersonic flow: Method of characteristics, wave	1	25%

	drag • Hypersonic flow: Newtonian theory, high-temperature effects • Viscous-inviscid interactions: Shock-boundary layer interaction • **Practical:** Nozzle design using method of characteristics, shock tube analysis		
III	**Viscous Flows & Boundary Layer Theory** **Topics:** • Boundary layer equations: Prandtl's approximations • Laminar boundary layers: Blasius solution, Falkner-Skan flows • Transition to turbulence: Stability theory, Tollmien-Schlichting waves • Turbulent boundary layers: Reynolds averaging, mixing length theory • Boundary layer separation: Effects of pressure gradient • Drag prediction: Skin friction, form drag, drag reduction techniques • **Practical:** Boundary layer calculations, transition prediction methods	1	25%
IV	**Computational & Specialized Aerodynamics** **Topics:** • Introduction to Computational Fluid Dynamics (CFD) • Turbulence modeling: RANS, LES, DES approaches • Unsteady aerodynamics: Wagner function, Theodorsen's theory • Rotor aerodynamics: Actuator disk theory, blade element theory • Aeroelasticity basics: Static divergence, flutter • Experimental techniques: Wind tunnel corrections, PIV, pressure measurements • **Practical:** CFD simulation of air foil/wing, comparison with experimental data	1	25%

TEXT BOOKS:

- Primary: *Foundations of Aerodynamics* (5th Ed.) — Arnold M. Kuethe & Chuen-Yen Chow
- Primary: *Fundamentals of Aerodynamics* (7th Ed.) — John D. Anderson, Jr.
- Primary: *Boundary Layer Theory* — Hermann Schlichting & Klaus Gersten

REFERENCE BOOKS:

- *Modern Compressible Flow: With Historical Perspective* (4th Ed.) — John D. Anderson, Jr.
- *Low-Speed Aerodynamics* (2nd Ed.) — Joseph Katz & Allen Plotkin
- *Aerodynamics for Engineering Students* (7th Ed.) — E.L. Houghton, P.W. Carpenter, Steven H. Collicott, Daniel T. Valentine

- *Theory of Wing Sections* — Ira H. Abbott & Albert E. von Doenhoff
- *Computational Fluid Dynamics: The Basics with Applications* — John D. Anderson, Jr.
- *Viscous Fluid Flow* (4th Ed.) — Frank M. White

ONLINE RESOURCES:

- NPTEL: Aerodynamics courses by IIT professors
- edX/Coursera: "Aerodynamics" by Delft University, "Flight Vehicle Aerodynamics" by MIT
- NASA Resources: Glenn Research Center Aerodynamics resources, FoilSim web tools
- SimScale: Cloud-based CFD platform for academic use

PRACTICAL LIST:

1. **Panel Method Implementation**
   - Code a 2D panel method for arbitrary air foil shapes
   - Calculate pressure distribution and lift coefficients
   - Compare results with XFOIL and experimental data
2. **Compressible Flow Analysis**
   - Design a supersonic nozzle using method of characteristics
   - Analyze transonic flow over air foil using available CFD software
   - Calculate wave drag for supersonic aircraft configurations
3. **Boundary Layer Analysis**
   - Solve Blasius equation numerically
   - Analyze boundary layer development over flat plate with pressure gradient
   - Predict transition location using e^N method
4. **CFD Project**
   - Option A: Simulation of flow over NACA 0012 airfoil at various angles of attack
   - Option B: Analysis of 3D wing with wingtip vortices
   - Requirements:
     1. Grid generation and independence study
     2. Selection of appropriate turbulence model
     3. Comparison with experimental/theoretical results
5. **Wind Tunnel Experimentation**
   - Pressure distribution measurement on airfoil model
   - Flow visualization using tufts/smoke
   - Boundary layer profile measurement using pitot tube
   - Data reduction and correction application

SUBJECT CODE: MTAE103

SUBJECT NAME: AIRCRAFT STRUCTURES AND AEROELASTICITY

Course Objectives:

- To provide advanced knowledge of aircraft structural analysis and design principles
- To understand aeroelastic phenomena and their impact on aircraft performance and stability
- To master analysis methods for composite structures and damage tolerance
- To develop skills in predicting and preventing structural failures due to aeroelastic effects
- To integrate structural design with aerodynamic requirements for optimal aircraft performance

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

CO1	**Analyze** complex aircraft structural components using energy methods and finite element analysis
CO2	**Evaluate** structural integrity considering fatigue, fracture, and damage tolerance
CO3	**Predict** aeroelastic instabilities: divergence, control reversal, and flutter
CO4	**Design** composite aircraft structures with proper ply orientation and stacking sequences

Unit	Content	Credit	Weightage
I	**Advanced Structural Analysis Methods** **Topics:** • Energy methods: Virtual work, Castigliano's theorems, Rayleigh-Ritz method • Matrix methods for indeterminate structures • Finite Element Analysis fundamentals for aircraft structures • Stress analysis of thin-walled structures: shear flow, torsion of multi-cell sections • Structural idealization: boom-skin idealization, shear lag effects • **Practical:** FEA modeling of wing box structure, stress concentration analysis	1	25%
II	**Aircraft Structural Design & Failure Analysis** **Topics:** • Aircraft load paths and structural layout principles • Fatigue analysis: S-N curves, Miner's rule, fatigue crack initiation • Fracture mechanics: Stress intensity factor, fracture toughness • Damage tolerance and fail-safe design philosophy • Composite structures: Lamina/laminate theory, failure criteria (Tsai-Hill, Tsai-Wu) • Sandwich construction and buckling analysis • **Practical:** Fatigue life prediction, composite	1	25%

	laminate design using CLT		
III	**Introduction to Aeroelasticity** **Topics:** • Static aeroelasticity: Divergence of lifting surfaces • Control effectiveness and control reversal • Influence coefficients and flexibility influence functions • Unsteady aerodynamics: Theodorsen function, Wagner function • Dynamic aeroelasticity: Flutter basics • Collar's triangle of forces (structural, inertial, aerodynamic) • **Practical:** Divergence speed calculation, control effectiveness analysis	1	25%
IV	**Advanced Aeroelasticity & Vibration** **Topics:** • Flutter analysis: Binary flutter, p-k method, V-g method • Torsional and bending-torsion flutter • Aero servo elasticity: Interaction with flight control systems • Vibration analysis: Natural frequencies, mode shapes, damping • Ground vibration testing (GVT) and modal analysis • Buffeting and gust response analysis • **Practical:** Flutter speed prediction for simple wing, modal analysis of cantilever beam	1	25%

TEXT BOOKS:

- Primary: *Aircraft Structures for Engineering Students* (7th Ed.) — T.H.G. Megson
- Primary: *Introduction to Aircraft Aeroelasticity and Loads* (2nd Ed.) — Jan R. Wright & Jonathan E. Cooper
- Primary: *Aeroelasticity* — Raymond L. Bisplinghoff, Holt Ashley, Robert L. Halfman

REFERENCE BOOKS:

- *Theory of Matrix Structural Analysis* — J.S. Przemieniecki
- *Composite Materials for Aircraft Structures* (3rd Ed.) — A. A. Baker, S. Dutton, D. Kelly
- *Analysis of Aircraft Structures: An Introduction* (2nd Ed.) — Bruce K. Donaldson
- *Aeroelasticity: The Continuum Theory* — Dewey H. Hodges & G. Alvin Pierce
- *Airframe Stress Analysis and Sizing* — Michael C.Y. Niu
- *Flutter of Aircraft Structures* — Earl H. Dowell

ONLINE RESOURCES:

- NPTEL: "Aircraft Structures" and "Aeroelasticity" courses by IITs
- MIT Open Course Ware: Aircraft Structures and Aeroelasticity materials
- AIAA eLearning: Professional courses on structures and dynamics
- NASA Technical Reports Server: Research papers and technical documents

PRACTICAL LIST:

1. **Structural Analysis Project**
   - Analyze a wing spar using energy methods and FEA
   - Compare results from analytical and numerical methods
   - Perform stress concentration analysis at cutouts
   - Document with validation against textbook examples
2. **Composite Structural Design**
   - Design a composite laminate for specific loading conditions
   - Perform failure analysis using different criteria
   - Optimize ply orientation for weight reduction
   - Analyze impact of delamination on structural integrity
3. **Aeroelastic Stability Analysis**
   - Calculate divergence speed for a cantilever wing
   - Analyze control reversal for an aileron
   - Perform simple flutter analysis using assumed modes
   - Investigate effect of structural stiffness on aeroelastic stability
4. **Vibration Testing & Analysis**
   - Conduct modal analysis on a cantilever beam/structure
   - Compare experimental natural frequencies with FEA predictions
   - Analyze damping characteristics from decay tests
   - Study effect of added mass on vibration modes
5. **Integrated Design Project (Capstone)**
   - Option A: Design and analyze a composite wing with aeroelastic constraints
   - Option B: Retrofit analysis for flutter clearance of existing design
   - Option C: Damage tolerance assessment of aircraft structural component
   - Requirements:
     1. Complete structural analysis (static, dynamic)
     2. Aeroelastic stability assessment
     3. Weight optimization considerations
     4. Compliance with airworthiness requirements
     5. Detailed technical report with recommendations

SUBJECT CODE: MTAE104

SUBJECT NAME: RESEARCH METHDOLOGY AND TECHNICAL COMMUNICATION

Course Objectives:

- To equip engineering graduates with a structured approach to scientific inquiry and problem-solving.
- To develop proficiency in selecting and applying appropriate research methods for engineering investigations.
- To enhance technical communication skills for academia and industry.
- To foster an understanding of research ethics, scholarly publishing, and lifelong learning in research.

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

CO1	Formulate a research problem, conduct systematic literature reviews, and develop a viable research proposal.
CO2	Design and execute appropriate research methodologies (experimental, numerical, analytical) with consideration for ethics and data integrity.

CO3	Apply statistical tools and software for data analysis, interpretation, and validation of research findings.
CO4	Produce high-quality technical documents (research papers, proposals, theses) and deliver effective technical presentations.

Unit	Content	Credit	Weightage
I	**Foundations of Engineering Research & Problem Formulation** • **Topics:** ◦ Philosophy of research: inductive vs. deductive reasoning, scientific method in engineering. ◦ Types of engineering research: fundamental, applied, experimental, computational, empirical. ◦ Problem identification and formulation: research gap analysis. ◦ Literature review strategies: databases (Scopus, Web of Science, IEEE Xplore), citation management tools (Zotero, Mendeley), critical analysis of literature. ◦ Developing a research proposal: objectives, scope, significance, and work plan. • **Applications:** Thesis topic selection, grant proposal writing, project planning.	1	25%
II	**Research Design, Methods & Ethics** • **Topics:** ◦ Research design: experimental, quasi-experimental, case study, modeling & simulation. ◦ Data collection methods: sensors, surveys, instrumentation, simulation outputs. ◦ Design of Experiments (DoE): factorial design, Taguchi methods, response surface methodology. ◦ Research ethics: plagiarism, fabrication/falsification, authorship, informed consent. ◦ Ethical approval process and responsible conduct of research (RCR). • **Applications:** Planning a lab/field experiment, setting up a CFD/FEA study, survey design.	1	25%
III	**Data Analysis, Statistics & Software Tools** • **Topics:** ◦ Data preprocessing: outlier detection, missing data, normalization. ◦ Descriptive and inferential statistics:	1	25%

	hypothesis testing (t-test, ANOVA), confidence intervals. ◦ Regression analysis: linear, multiple, logistic. ◦ Introduction to multivariate analysis and machine learning for engineering data. ◦ Software tools: MATLAB/Python (NumPy, SciPy, pandas), R, MiniTab. ◦ Data visualization principles: effective graphs, charts, and plots. • **Applications:** Analyzing experimental results, validating computational models, interpreting sensor data.		
IV	**Technical Communication & Research Dissemination** • **Topics:** ◦ Structure of technical documents: research papers, theses, technical reports. ◦ Writing strategies: clarity, conciseness, coherence, and argument development. ◦ Graphical abstracts, data presentation, and table/figure design. ◦ Oral presentations: conference talks, thesis defense, poster design. ◦ Publication process: journal selection, peer review, responding to reviewers. ◦ Intellectual Property Rights (IPR): patents, copyrights, licensing. ◦ Research dissemination: repositories, academic social networks (ResearchGate, LinkedIn), and impact metrics (h-index, citations). • **Applications:** Paper writing, thesis compilation, conference presentation, patent filing.	1	25%

TEXT BOOKS:

- Kothari, C.R. – *Research Methodology: Methods and Techniques* (4th ed.) – New Age International.
- Day, R.A., and Gastel, B. – *How to Write and Publish a Scientific Paper* (9th ed.) – Greenwood.
- Montgomery, D.C. – *Design and Analysis of Experiments* (10th ed.) – Wiley.
- Alley, M. – *The Craft of Scientific Writing* (4th ed.) – Springer.

REFERENCE BOOKS:

- Bordens, K.S., and Abbott, B.B. – *Research Design and Methods: A Process Approach* (11th ed.) – McGraw-Hill.
- Wallwork, A. – *English for Writing Research Papers* (2nd ed.) – Springer.
- Box, G.E.P., Hunter, J.S., and Hunter, W.G. – *Statistics for Experimenters* (2nd ed.) – Wiley.

- IEEE Author Center Guides – *IEEE Publication Services and Products Board.*
- Laplante, P.A. – *Technical Writing: A Practical Guide for Engineers and Scientists* – CRC Press.

ONLINE RESOURCES:

- edX Courses:
  1. *"Principles of Statistical Analysis"* (Microsoft)
  2. *"How to Write and Publish a Scientific Paper"* (KU Leuven)

SUBJECT CODE: MTAE105

SUBJECT NAME: ENTERPRENURSHIP DEVELOPMENT

Course Objectives:

- To cultivate an entrepreneurial mindset among engineering graduates.
- To provide practical tools for transforming technical ideas into viable business ventures.
- To develop skills in business modeling, financial planning, and venture funding.
- To prepare students for startup creation, intrapreneurship, or technology commercialization roles.

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

CO1	Identify and evaluate entrepreneurial opportunities emerging from technological trends and market gaps.
CO2	Develop a comprehensive business model and validate it using lean startup methodologies and customer discovery.
CO3	Create financial projections, evaluate startup costs, and understand funding mechanisms for technology ventures.
CO4	Formulate a complete investor-ready business plan and deliver an effective pitch to potential stakeholders.

Unit	Content	Credit	Weightage

I	**Entrepreneurial Mindset & Opportunity Identification**
	• **Topics:**
	  ○ The Entrepreneurial Engineer: Mindset, traits, and role in economic development.
	  ○ Sources of Innovation: Technology push vs. market pull, disruptive vs. sustaining innovation.
	  ○ Opportunity Recognition: Identifying problems worth solving, trend analysis (STEEP), blue ocean strategy.
	  ○ Idea Validation: Lean canvas, hypothesis testing, conducting problem-solution interviews.
	  ○ Intellectual Property Strategy for Startups: Patents, trademarks, trade secrets, and licensing basics.
	• **Applications:** Spotting opportunities in cleantech, Industry 4.0, medtech, and digital transformation.
		1	25%

II	**Business Model Design & Customer Development**
	
	• **Topics:**
	  ○ Business Model Innovation: Business Model Canvas (Osterwalder), Value Proposition Canvas.
	  ○ Customer Discovery & Validation: The "Get Out of the Building" approach, creating MVP (Minimum Viable Product).
	  ○ Market Analysis: TAM, SAM, SOM, competitive analysis, positioning.
	  ○ Pricing Strategies for Tech Products: Cost-plus, value-based, subscription, freemium models.
	  ○ Go-to-Market Strategy: Sales channels, partnerships, digital marketing fundamentals.
	• **Applications:** Designing scalable models for SaaS, hardware-as-a-service, platform businesses.
		1	25%

III	**Startup Finance, Funding & Legal Foundations**
	
	• **Topics:**
	  ○ Startup Financials: Building financial models, unit economics, burn rate, runway.
	  ○ Pro Forma Statements: Income statement, cash flow, balance sheet projections.
	  ○ Funding Sources: Bootstrapping, angels, venture capital, crowdfunding, government grants (SBIR, DST).
	  ○ Valuation Methods for Early-Stage Startups: Scorecard, Berkus, risk factor summation.
	  ○ Legal Structures & Compliance: Company registration (LLP, Pvt Ltd), shareholder agreements, ESOPs, compliance essentials.
	  ○ Term Sheet Fundamentals: Key clauses, negotiation basics.
	• **Applications:** Preparing for seed funding, managing cash flow, cap table management.
		1	25%

IV	**Business Planning, Pitching & Scaling Ventures**
	• **Topics:**
	  ○ The Business Plan: Executive summary, company description, product/service, market analysis, marketing plan, management team, financial projections.
	  ○ The Art of Pitching: Investor pitch deck
		1	25%

	structure, storytelling, demo preparation. ◦ Building the Team: Co-founder selection, hiring early employees, advisory boards. ◦ Operational Planning: Supply chain, quality, scaling production. ◦ Growth Strategies: Scaling challenges, pivoting, exit strategies (acquisition, IPO). ◦ Social Entrepreneurship & Ethics: Creating social impact, ethical leadership. • **Applications:** Crafting investor pitches, developing operational roadmaps, planning for scale.		

TEXT BOOKS:

- Osterwalder, A., and Pigneur, Y. – *Business Model Generation* – Wiley.
- Ries, E. – *The Lean Startup* – Penguin.
- Blank, S., and Dorf, B. – *The Startup Owner's Manual* – K & S Ranch.
- Barrow, C., Barrow, P., and Brown, R. – *The Business Plan Workbook* (10th ed.) – Kogan Page.

REFERENCE BOOKS:

- Aulet, B. – *Disciplined Entrepreneurship* – Wiley.
- Mullins, J. – *The New Business Road Test* (5th ed.) – FT Publishing.
- Kawasaki, G. – *The Art of the Start 2.0* – Portfolio Penguin.
- Thiel, P. – *Zero to One* – Crown Business.
- Maurya, A. – *Running Lean* (2nd ed.) – O'Reilly.

ONLINE RESOURCES:

- Coursera: *"Entrepreneurship Specialization"* (Wharton), *"Startup Entrepreneurship"* (Technion).
- edX: *"Entrepreneurship in Emerging Economies"* (HarvardX), *"Innovation and Entrepreneurship"* (DelftX).

Udemy: Courses on Business Plan Writing, Startup Funding, and Digital Marketing.

SEMESTER-II

SUBJECT CODE: MTAE201

SUBJECT NAME: ADVANCED AEROSPACE MATERIALS

Course Objectives:

- To understand the selection criteria, properties, and applications of advanced materials in aerospace systems
- To explore material behavior under extreme aerospace environments: high temperature, cryogenic, radiation, and corrosive conditions
- To master composite material systems including polymer, metal, and ceramic matrix composites
- To study advanced manufacturing, joining, and repair techniques for aerospace materials
- To examine material degradation mechanisms, non-destructive evaluation (NDE), and life prediction methodologies

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

CO1	**Select appropriate materials** for specific aerospace applications based on performance requirements
CO2	**Analyze composite materials** using micromechanics and laminate plate theory
CO3	**Evaluate material degradation** mechanisms including fatigue, creep, corrosion, and oxidation
CO4	**Design with advanced materials** considering manufacturing constraints and life-cycle costs

Unit	Content	Credit	Weightage
I	**Metallic Aerospace Materials** **Topics:** • Advanced aluminum alloys: 2XXX, 7XXX series, Al-Li alloys • Titanium alloys: α, β, α-β alloys, superplastic forming • High-temperature materials: Nickel-based superalloys, cobalt alloys • Magnesium alloys and emerging metallic systems • Material selection methodology: Ashby charts, performance indices • Heat treatment and surface engineering for aerospace applications • **Key Applications:** Airframe structures, engine components, landing gear	1	25%
II	**Composite Material Systems** **Topics:** • Reinforcement materials: Carbon, glass, aramid, and ceramic fibers • Matrix systems: Thermosets (epoxy, BMI, polyimide), thermoplastics (PEEK, PEKK)	1	25%

	• Micromechanics: Rule of mixtures, Halpin-Tsai equations • Laminate analysis: Classical Laminate Plate Theory (CLT), failure criteria (Tsai-Wu, Tsai-Hill) • Sandwich structures: Core materials, failure modes, design considerations • Metal Matrix Composites (MMCs) and Ceramic Matrix Composites (CMCs) • **Key Applications:** Primary structures, engine components, thermal protection systems		
III	**Manufacturing & Processing** **Topics:** • Composite manufacturing: Autoclave curing, RTM, VARTM, filament winding • Additive manufacturing for aerospace: DMLS, EBAM, FDM with high-performance materials • Joining technologies: Adhesive bonding, mechanical fastening, co-curing, welding of dissimilar materials • Repair techniques: Bolted and bonded repairs, scarf repairs, SMART patches • Quality control and process optimization • Environmental and economic aspects of manufacturing • **Key Processes:** Automated fiber placement, resin infusion, powder bed fusion	1	25%
IV	**Performance & Durability** **Topics:** • Material behavior in extreme environments: High temperature, cryogenic, space radiation • Degradation mechanisms: Fatigue, creep, corrosion, oxidation, UV degradation • Damage tolerance: Impact damage, delamination growth, fracture mechanics approach • Non-destructive Evaluation (NDE): Ultrasonic C-scan, thermography, X-ray CT, acoustic emission • Smart materials and structures: SHM systems, self-healing materials • Life prediction and certification methodologies • **Key Issues:** Bird strike resistance, lightning strike protection, thermal barrier coatings	1	25%

TEXT BOOKS:

- Primary: *Composite Materials for Aircraft Structures* (3rd Ed.) — A.A. Baker, S. Dutton, D. Kelly
- Primary: *Aerospace Materials and Applications* — Biliyar N. Bhat, Timothy S. Bessmann, et al. (AIAA)

- Primary: *Introduction to Aerospace Materials* — Adrian P. Mouritz

REFERENCE BOOKS:

- *Materials Science and Engineering: An Introduction* (10th Ed.) — William D. Callister, David G. Rethwisch
- *Engineering Mechanics of Composite Materials* (2nd Ed.) — Isaac M. Daniel, Ori Ishai
- *High Temperature Materials and Mechanisms* — Yoseph Bar-Cohen
- *Smart Structures and Materials* — B. Culshaw
- *Handbook of Advanced Materials: Enabling New Designs* — James K. Wessel
- *Fracture and Fatigue of Composite Materials* — Ramesh Talreja, Janis Varna

ONLINE RESOURCES:

- NPTEL: "Composite Materials" and "Advanced Materials" courses by IITs
- edX: "Materials Science & Engineering" by MIT, "Materials in Aeronautics" by Delft
- NASA Technical Reports Server (NTRS): Research on aerospace materials
- ASM International: Online learning modules and handbooks

SUBJECT CODE: MTAE202

SUBJECT NAME: FLIGHT DYNAMICS AND CONTROL

Course Objectives:

- To develop mathematical models of aircraft dynamics from first principles
- To analyze aircraft stability characteristics in longitudinal and lateral-directional modes
- To design classical and modern flight control systems
- To understand handling qualities and certification requirements
- To explore advanced topics in nonlinear dynamics, flight simulation, and autonomous systems

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

CO1	**Derive equations of motion** for rigid aircraft using Newton-Euler formulation
CO2	**Linearize nonlinear models** and analyze stability using eigenvalue methods
CO3	**Design stability augmentation systems** (SAS) and autopilots
CO4	**Evaluate handling qualities** using Cooper-Harper and MIL-STD-1797 criteria

Unit	Content	Credit	Weightage
I	**Aircraft Equations of Motion & Stability Derivatives** **Topics:** • Coordinate systems: Earth, body, wind, and stability axes • Rigid body equations: Newton-Euler formulation, Euler angles, quaternions • Aerodynamic forces and moments modeling • Stability derivatives: physical significance, estimation methods • Linearization: small perturbation theory, state-space representation	1	25%

	• **Practical:** Derivation of equations for a specific aircraft, stability derivative calculation		
II	**Longitudinal & Lateral-Directional Dynamics** **Topics:** • Longitudinal modes: phugoid and short period characteristics • Lateral-directional modes: Dutch roll, roll subsidence, spiral mode • Modal analysis: eigenvalues, eigenvectors, time responses • Stability criteria: Routh-Hurwitz, Nyquist, Bode plots • Handling qualities: Cooper-Harper scale, MIL-STD-1797 requirements • **Practical:** Mode extraction from flight data, handling qualities assessment	1	25%
III	**Classical Flight Control Design** **Topics:** • Stability augmentation systems (SAS): yaw damper, pitch damper • Autopilot design: altitude hold, heading hold, glide slope tracking • Control allocation: mixing logic for redundant effectors • Gain scheduling for nonlinear flight envelope • Control system implementation: digital implementation issues • **Practical:** Design of SAS for unstable aircraft, autopilot implementation in Simulink	1	25%
IV	**Advanced Topics & Nonlinear Dynamics** **Topics:** • Nonlinear phenomena: stall, spin, wing rock, limit cycles • Bifurcation analysis and continuation methods • Robust control: H-infinity, μ-synthesis applications • Adaptive control and reconfigurable flight control • Fly-by-wire systems: architecture, redundancy management • Autonomous flight: path planning, guidance laws • **Practical:** Nonlinear simulation of spin recovery, robust controller design	1	25%

TEXT BOOKS:

- Primary: *Aircraft Dynamics and Automatic Control* — Duane McRuer, Irving Ashkenas, Dunstan Graham
- Primary: *Dynamics of Flight: Stability and Control* (3rd Ed.) — Bernard Etkin & Lloyd Duff Reid

- Primary: *Flight Dynamics* — Robert F. Stengel

REFERENCE BOOKS:

- *Aircraft Control and Simulation* (3rd Ed.) — Brian L. Stevens, Frank L. Lewis, Eric N. Johnson
- *Applied Nonlinear Dynamics: Analytical, Computational and Experimental Methods* — Ali H. Nayfeh & Balakumar Balachandran
- *Small Unmanned Aircraft: Theory and Practice* — Randal W. Beard & Timothy W. McLain
- *Advanced Flight Dynamics with Elements of Flight Control* — N. Ananthkrishnan & A. S. Shyam
- *Introduction to Flight Testing and Applied Aerodynamics* — Barnes W. McCormick

ONLINE RESOURCES:

- NPTEL: "Flight Dynamics" by IIT Bombay, "Flight Mechanics" by IIT Kanpur
- MIT OpenCourseWare: Aircraft Stability and Control materials
- AIAA eLearning: Professional short courses on flight dynamics
- NASA Technical Reports Server (NTRS): Historical flight test data and reports

PRACTICAL LIST:

1. **Aircraft Modeling Project**
   - Derive complete nonlinear equations of motion for a given aircraft
   - Calculate stability derivatives using DATCOM or analytical methods
   - Linearize model at multiple flight conditions
   - Validate with published data or wind tunnel results
2. **Stability Analysis & Handling Qualities**
   - Extract longitudinal and lateral modes from linearized models
   - Plot root locus with varying parameters (CG position, speed)
   - Perform handling qualities assessment using MIL-STD criteria
   - Compare different aircraft configurations (fighter vs transport)
3. **Flight Control System Design**
   - Design yaw damper for Dutch roll damping
   - Implement altitude hold autopilot with gain scheduling
   - Add turn coordination logic for banked turns
   - Test in nonlinear simulation with atmospheric disturbances
4. **Nonlinear Dynamics Investigation**
   - Simulate departure maneuvers leading to stall/spin
   - Analyze spin recovery using anti-spin parachute modeling
   - Investigate limit cycle oscillations (e.g., wing rock)
   - Perform bifurcation analysis with varying parameters

Comprehensive Flight Simulation (Capstone)

- Option A: Design fly-by-wire system for unstable aircraft
- Option B: Develop autonomous landing system
- Option C: Create upset recovery system
- **Requirements:**
  - High-fidelity nonlinear model
  - Control system with redundancy management
  - Monte Carlo simulation for robustness testing
  - Handling qualities evaluation
  - Real-time simulation demonstration

SUBJECT CODE: MTAE203

SUBJECT NAME: SPACE MECHANICS AND SATELLITE TECHNOLOGY

Course Objectives:

- To provide an in-depth understanding of celestial mechanics and orbital dynamics
- To analyze satellite mission design, orbital maneuvers, and station-keeping strategies
- To study satellite subsystems, their design, and integration
- To explore satellite applications in communication, remote sensing, navigation, and space science
- To examine launch vehicles, space environment effects, and space mission operations

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

CO1	**Solve orbital mechanics problems** including perturbed motion and orbit determination
CO2	**Design satellite missions** for specific applications (Earth observation, communication, navigation)
CO3	**Analyze satellite subsystems** (power, thermal, AOCS, propulsion, communication)
CO4	**Plan orbital maneuvers** (Hohmann transfers, plane changes, rendezvous)

Unit	Content	Credit	Weightage
I	**Advanced Orbital Mechanics** **Topics:** • Two-body and restricted three-body problems • Keplerian orbits: orbital elements, time of flight equations • Orbital perturbations: J_2 effect, atmospheric drag, third-body effects • Orbit determination: Gibbs and Gauss methods, Kalman filtering • Orbital maneuvers: Hohmann transfers, bi-elliptic transfers, plane changes • Rendezvous and proximity operations: Clohessy-Wiltshire equations • **Practical:** Orbit propagation with perturbations, rendezvous simulation	1	25%
II	**Satellite Mission Design** **Topics:** • Mission analysis: requirements definition, concept of operations • Orbit selection: LEO, MEO, GEO, HEO, Molniya, Sun-synchronous orbits • Launch vehicle interface: injection conditions, orbit raising • Space environment: vacuum, radiation, thermal, micrometeoroids • Constellation design: Walker constellations,	1	25%

	coverage analysis • Satellite reliability and redundancy • **Practical:** Mission design for Earth observation, coverage analysis		
III	**Satellite Subsystems** **Topics:** • Structure and mechanisms: materials, deployables, vibration analysis • Power systems: solar arrays, batteries, power conditioning • Thermal control: passive and active systems, radiators • Attitude determination and control: sensors, actuators, control laws • Communication systems: transponders, antennas, link budget • Propulsion: chemical, electric, cold gas systems • **Practical:** Link budget calculation, power budget analysis	1	25%
IV	**Satellite Applications & Operations** **Topics:** • Communication satellites: frequency bands, multiple access techniques • Remote sensing: optical, infrared, microwave sensors • Navigation systems: GPS, GLONASS, Galileo, BeiDou • Scientific satellites: space telescopes, planetary missions • Ground segment: tracking, telemetry, command, data processing • Space debris: mitigation, tracking, removal technologies • CubeSats and small satellite revolution • **Practical:** Image processing from remote sensing data, GPS position determination	1	25%

TEXT BOOKS:

- Primary: *Fundamentals of Astrodynamics and Applications* (5th Ed.) — David A. Vallado
- Primary: *Satellite Technology: Principles and Applications* (4th Ed.) — Anil K. Maini & Varsha Agrawal
- Primary: *Spacecraft Dynamics and Control: A Practical Engineering Approach* — Marcel J. Sidi

REFERENCE BOOKS:

- *Space Mission Analysis and Design* (3rd Ed.) — James R. Wertz & Wiley J. Larson
- *Orbital Mechanics for Engineering Students* (4th Ed.) — Howard D. Curtis
- *Spacecraft Systems Engineering* (5th Ed.) — Peter Fortescue, Graham Swinerd, John Stark

- *Introduction to Satellite Communication* (3rd Ed.) — Bruce R. Elbert
- *Spacecraft Thermal Control Handbook* (2nd Ed.) — David G. Gilmore
- *Theory of Orbit Determination* — Andrea Milani & Giovanni F. Gronchi

ONLINE RESOURCES:

- NPTEL: "Space Flight Mechanics" by IIT Kharagpur, "Satellite Technology" by ISRO scientists
- edX: "Space Mission Design and Operations" by EPFL, "Orbital Mechanics" by MIT
- ISRO e-Learning: Indian Space Research Organization's learning portal
- NASA Open Data: Satellite datasets, mission design documents

PRACTICAL LIST:

1. **Orbit Propagation & Maneuver Planning**
   - Propagate satellite orbit with J_2 perturbation and atmospheric drag
   - Design Hohmann transfer between LEO and GEO
   - Calculate ΔV requirements for station-keeping maneuvers
   - Simulate rendezvous with target spacecraft
2. **Satellite Mission Design Project**
   - Design a complete Earth observation mission
   - Select appropriate orbit (Sun-synchronous parameters)
   - Calculate revisit time, coverage area
   - Perform launch window analysis
   - Prepare preliminary mission operations plan
3. **Satellite Subsystem Design Exercise**
   - Design power subsystem for given satellite mission
   - Calculate solar array size, battery capacity
   - Perform link budget analysis for communication system
   - Design thermal control for specific orbital conditions
   - Calculate mass budget and preliminary cost estimate
4. **Remote Sensing Data Analysis**
   - Download satellite imagery (Sentinel, Landsat)
   - Perform basic image processing operations
   - Extract information: land use, vegetation indices, water bodies
   - Compare multi-spectral bands for different applications
5. **End-to-End Mission Simulation (Capstone)**
   - Option A: Design a lunar mission with orbiter component
   - Option B: Design a regional communication satellite system
   - Option C: Create a disaster monitoring satellite constellation
   - **Requirements:**
     1. Complete mission design document
     2. Orbital analysis with perturbation effects
     3. Subsystem specifications and budgets
     4. Ground station network design
     5. Cost and schedule estimation
     6. Risk assessment and mitigation

SUBJECT CODE: MTAE204

SUBJECT NAME: AEROACOUSTICS

Course Objectives:

- To understand the fundamental principles of sound generation, propagation, and perception in aerospace contexts
- To analyze noise generation mechanisms in aircraft: jet, fan, airframe, and combustion noise
- To master analytical and computational methods for aeroacoustic prediction
- To study noise reduction techniques and regulatory frameworks
- To explore advanced topics: supersonic jet noise, rotor acoustics, and aeroacoustic testing

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

CO1	**Derive** acoustic wave equations from fluid dynamic principles
CO2	**Identify** and **model** dominant noise sources in aircraft and turbomachinery
CO3	**Apply** analytical methods (Lighthill's analogy, FW-H equation) to predict sound radiation
CO4	**Design** noise reduction strategies using passive and active methods

Unit	Content	Credit	Weightage
I	**Fundamentals of Acoustics & Aeroacoustic Theory** **Topics:** • Wave equation derivation from fluid dynamics • Solutions to wave equation: plane waves, spherical waves, Green's functions • Sound propagation: refraction, diffraction, reflection • Acoustic intensity, power, and decibel scales • Human perception: loudness, A-weighting, speech interference level • Lighthill's acoustic analogy: derivation and physical interpretation • **Practical:** Analytical solutions to wave equation, sound propagation simulations	1	25%
II	**Aircraft Noise Sources** **Topics:** • Jet noise: Lighthill's eighth-power law, mixing noise, broadband shock noise • Fan and compressor noise: rotor-stator interaction, buzz saw noise • Airframe noise: landing gear, high-lift devices, cavity oscillations • Combustion noise: direct and indirect noise • Helicopter rotor noise: thickness noise, loading noise, blade-vortex interaction • Sonic boom: N-wave formation, shaping for	1	25%

	minimized impact • **Practical:** Source identification from spectra, jet noise scaling laws		
III	**Analytical & Computational Methods** **Topics:** • Fowcs Williams-Hawkings (FW-H) equation for moving surfaces • Kirchhoff method for noise propagation • Boundary Element Method (BEM) for acoustic radiation • Computational Aeroacoustics (CAA): governing equations, numerical methods • Hybrid approaches: CFD/CAA coupling • Statistical Energy Analysis (SEA) for high-frequency problems • **Practical:** Implementation of FW-H solver, simple CAA code development	1	25%
IV	**Noise Control & Measurement** **Topics:** • Passive noise control: acoustic liners, nacelle design, chevron nozzles • Active noise control: principles, adaptive algorithms, implementation challenges • Structural-acoustic coupling and vibration damping • Aeroacoustic testing: wind tunnels, anechoic chambers, outdoor testing • Measurement techniques: microphone arrays, phased arrays, acoustic cameras • Noise certification: FAR Part 36, ICAO Chapters, community noise metrics • **Practical:** Design of acoustic liner, array signal processing	1	25%

TEXT BOOKS:

- Primary: *Aeroacoustics* — Christopher K. W. Tam
- Primary: *Aeroacoustics of Flight Vehicles: Theory and Practice* (Vol. 1 & 2) — Harvey H. Hubbard (Editor)
- Primary: *Theoretical Acoustics* — Philip M. Morse & K. Uno Ingard

REFERENCE BOOKS:

- *Aeroacoustics: Fundamentals and Applications in Aerodynamics and Acoustics* — S. R. Ahmed
- *Computational Aeroacoustics: A Wave Number Approach* — Christopher K. W. Tam
- *Noise and Vibration Control Engineering: Principles and Applications* (3rd Ed.) — István L. Vér & Leo L. Beranek
- *Jet Noise* — T. F. Balsa & M. M. Gliebe
- *Handbook of Acoustics* (2nd Ed.) — Malcolm J. Crocker
- *Rotating Blade Flow and Noise* — F. Farassat

ONLINE RESOURCES:

- NPTEL: "Aeroacoustics" by IITs, "Noise Control Engineering"
- MIT OpenCourseWare: "Fundamentals of Acoustics" and related courses
- AIAA eLearning: Professional short courses on aeroacoustics
- NASA Technical Reports Server (NTRS): Research papers on jet noise, fan noise

PRACTICAL LIST:

1. **Fundamental Acoustics Laboratory**
   - Measurement of sound pressure levels and frequency analysis
   - Reverberation time measurement in different environments
   - Sound transmission loss measurement through partitions
   - Impedance tube measurements for acoustic materials
2. **Aircraft Noise Source Analysis**
   - Analyze spectral data from different aircraft components
   - Identify noise sources from time-frequency representations (spectrograms)
   - Apply scaling laws to predict noise from geometric and flow parameters
   - Compare subsonic vs. supersonic jet noise characteristics
3. **Computational Aeroacoustics Project**
   - Simulate sound radiation from a circular cylinder (2D laminar flow)
   - Implement FW-H solver for moving dipole source
   - Perform CAA simulation using finite difference methods
   - Validate results with analytical solutions or experimental data
4. **Noise Reduction Design Exercise**
   - Design acoustic liner for turbofan inlet
   - Optimize chevron nozzle geometry for jet noise reduction
   - Simulate active noise control system for cabin noise
   - Perform cost-benefit analysis of noise reduction technologies
5. **Comprehensive Aeroacoustic Analysis (Capstone)**
   - Option A: Complete noise analysis for regional aircraft
   - Option B: Design low-noise UAV propulsion system
   - Option C: Sonic boom minimization for supersonic business jet
   - **Requirements:**
     1. Identify dominant noise sources
     2. Predict noise levels using appropriate methods
     3. Design noise reduction solutions
     4. Evaluate regulatory compliance
     5. Community noise impact assessment

MK UNIVERSITY

PATAN, GUJARAT

ESTABLISHED BY THE GUJARAT GOVT. RECOGNIZED BY UGC UNDER SECTION 2(f) OF UGC ACT,1956

SEMESTER-III

SUBJECT CODE: MTAE301

SUBJECT NAME: TURBULANCE MODELING

Course Objectives:

- To understand the fundamental physics and statistical description of turbulent flows
- To derive and analyze Reynolds-Averaged Navier-Stokes (RANS) equations and closure models
- To study Large Eddy Simulation (LES) and hybrid RANS-LES methodologies
- To implement and validate turbulence models for aerospace applications
- To examine advanced topics: transition modeling, compressible turbulence, and data-driven approaches

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

CO1	**Derive** statistical descriptions of turbulence and Reynolds decomposition
CO2	**Analyze** RANS closure models: eddy viscosity and Reynolds stress models
CO3	**Implement** turbulence models in simplified CFD codes
CO4	**Evaluate** model performance for different flow configurations

Unit	Content	Credit	Weightage
I	**Fundamentals of Turbulence & Statistical Description** **Topics:** • Nature of turbulence: randomness, vorticity, energy cascade • Reynolds decomposition and averaging procedures • Reynolds-Averaged Navier-Stokes (RANS) equations derivation • Turbulent kinetic energy budget and scales of motion • Kolmogorov hypotheses and energy spectrum • Direct Numerical Simulation (DNS): capabilities and limitations • **Practical:** Statistical analysis of turbulent flow data, energy spectrum calculation	1	25%
II	**RANS Modeling Approaches** **Topics:** • Eddy viscosity concept: Boussinesq hypothesis • Zero-equation models: Mixing length, Cebeci-Smith • One-equation models: Spalart-Allmaras model • Two-equation models: k-ε family (Standard, RNG, Realizable), k-ω family (Wilcox, SST) • Reynolds Stress Models (RSM): Algebraic and differential formulations • Near-wall treatment: wall functions vs. low-Re models	1	25%

	• **Practical:** Implementation of k-ε model in simple 1D code, boundary layer simulation		
III	**Scale-Resolving Simulation Methods** **Topics:** • Large Eddy Simulation (LES): filtering operations, subgrid-scale models • Smagorinsky model and dynamic procedure • Detached Eddy Simulation (DES) and its variants: DDES, IDDES • Wall-modeled LES (WMLES) for high Reynolds number flows • Hybrid RANS-LES methods: zonal approaches • Numerical requirements for LES: grid resolution, time stepping • **Practical:** LES of decaying isotropic turbulence, channel flow simulation	1	25%
IV	**Advanced Topics & Applications** **Topics:** • Transition modeling: γ-Reθ model, laminar kinetic energy • Compressible turbulence modeling: dilatational dissipation, shock-turbulence interaction • Turbulence in rotating flows and curvature effects • Data-driven turbulence modeling: machine learning approaches • Uncertainty quantification in turbulence modeling • Best practices for industrial CFD applications • **Practical:** Transition prediction for airfoil, data assimilation for model correction	1	25%

TEXT BOOKS:

- Primary: *Turbulence Modeling for CFD* (3rd Ed.) — David C. Wilcox
- Primary: *Statistical Theory and Modeling for Turbulent Flows* (2nd Ed.) — P. A. Durbin & B. A. Pettersson Reif
- Primary: *Large-Eddy Simulation for Incompressible Flows* — Pierre Sagaut

REFERENCE BOOKS:

- *Turbulent Flows* — Stephen B. Pope
- *An Introduction to Turbulence Models* — Lars Davidson
- *Turbulence: An Introduction for Scientists and Engineers* — Peter S. Davidson
- *Numerical Heat Transfer and Fluid Flow* — Suhas V. Patankar
- *Theories of Turbulence* — Martin Oberlack et al.
- *Data-Driven Fluid Mechanics: Combining First Principles and Machine Learning* — Miguel A. Mendez et al.

ONLINE RESOURCES:

- NPTEL: "Turbulence" by IITs, "Computational Fluid Dynamics"
- edX/Coursera: "Turbulence at the Crossroads" by École Polytechnique, "Data-Driven Turbulence Modeling"

- NASA's Turbulence Modeling Resource: Extensive documentation and validation cases
- Johns Hopkins Turbulence Databases (JHTDB): Direct Numerical Simulation data

PRACTICAL LIST:

1. **Fundamental Turbulence Analysis**
   - Analyze DNS/LES database (channel flow, isotropic turbulence)
   - Calculate Reynolds stresses, turbulent kinetic energy budget
   - Plot energy spectrum, verify Kolmogorov scaling
   - Perform proper orthogonal decomposition (POD) on flow field
2. **RANS Model Implementation & Comparison**
   - Implement 1D boundary layer solver with different turbulence models
   - Compare mixing length, k-ε, and k-ω models for flat plate flow
   - Analyze sensitivity to model constants and near-wall treatment
   - Validate against experimental data or DNS results
3. **Scale-Resolving Simulation Project**
   - Perform LES of backward-facing step flow
   - Compare different subgrid-scale models (Smagorinsky, dynamic, WALE)
   - Analyze coherent structures using Q-criterion or λ_2
   - Compare results with RANS simulations
4. **Aerospace Application Case Study**
   - Option A: Turbulent flow over airfoil at high angle of attack
   - Option B: Jet in crossflow simulation
   - Option C: Turbine blade passage flow

Advanced Research Project (Capstone)

- Option A: Develop machine learning correction to existing turbulence model
- Option B: Implement and test new transition model
- Option C: Uncertainty quantification for CFD predictions

SUBJECT CODE: MTAE302

SUBJECT NAME: HELICOPTER AERODYNAMICS

Course Objectives:

- To understand the fundamental aerodynamic principles unique to rotary-wing aircraft
- To analyze rotor blade aerodynamics including blade element theory and vortex methods
- To study helicopter performance in hover, forward flight, and maneuver conditions
- To examine rotorcraft stability, control, and handling qualities
- To explore advanced topics: compound helicopters, tiltrotors, and UAV rotor systems

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

CO1	**Analyze** rotor aerodynamics using momentum and blade element theories
CO2	**Predict** helicopter performance in hover, climb, and forward flight
CO3	**Model** rotor wake using vortex methods and understand ground effect
CO4	**Evaluate** rotorcraft stability derivatives and control response

Unit	Content	Credit	Weightage
I	**Fundamentals of Rotor Aerodynamics** **Topics:** • Momentum theory: hover, vertical climb, and forward flight • Blade element theory: differential thrust and torque • Combined blade element momentum theory (BEMT) • Rotor figure of merit and power requirements • Ground effect: theory and practical implications • Autorotation: energy balance and descent rates • **Practical:** BEMT implementation for rotor performance prediction	1	25%
II	**Rotor Blade Analysis & Wake Modeling** **Topics:** • Airfoil selection for rotorcraft: camber, thickness, stall characteristics • Blade twist and taper optimization • Vortex theory: prescribed wake, free wake, vortex lattice methods • Dynamic inflow and wake distortion • Rotor-turbulence interaction • Retreating blade stall and compressibility effects • **Practical:** Vortex wake modeling for rotor in hover and forward flight	1	25%
III	**Helicopter Performance & Stability**	1	25%

	Topics: • Power required vs. power available diagrams • Hover performance ceiling and forward flight envelope • Climb performance and maximum rate of climb • Maneuver performance: turns, pull-ups, acceleration • Static and dynamic stability derivatives • Control response: heave, pitch, roll, yaw axes • Handling qualities: ADS-33 requirements • **Practical:** Performance calculation for mission analysis		
IV	**Advanced Topics & Special Configurations** **Topics:** • Tail rotor aerodynamics and anti-torque devices • Fenestron and NOTAR systems • Compound helicopters: wings, propellers, and auxiliary propulsion • Tiltrotor aerodynamics: conversion corridor • Coaxial and tandem rotor systems • Unmanned rotorcraft: scaling effects and unique challenges • Noise generation and reduction techniques • **Practical:** Comparative analysis of different rotorcraft configurations	1	25%

TEXT BOOKS:

- Primary: *Principles of Helicopter Aerodynamics* (2nd Ed.) — J. Gordon Leishman
- Primary: *Helicopter Performance, Stability, and Control* — Raymond W. Prouty
- Primary: *Rotorcraft Aeromechanics* — Wayne Johnson

REFERENCE BOOKS:

- *Bramwell's Helicopter Dynamics* (2nd Ed.) — George Done & David Balmford
- *Helicopter Theory* — Alfred Gessow & Garry C. Myers
- *The Art of the Helicopter* — John Watkinson
- *Aerodynamics of the Helicopter* — Alfred Gessow
- *Rotary Wing Structural Dynamics and Aeroelasticity* — Richard L. Bielawa
- *Introduction to VTOL Airplanes* — Peter W. Brooks

ONLINE RESOURCES:

- NPTEL: "Helicopter Engineering" by IITs, "Rotorcraft Aerodynamics"
- University of Maryland Rotorcraft Center: Online resources and publications
- NASA Technical Reports Server (NTRS): Rotorcraft research papers
- American Helicopter Society (AHS) International: Technical resources

PRACTICAL LIST:

1. **Rotor Performance Analysis Using BEMT**
   - Develop BEMT code for rotor in hover
   - Extend to forward flight with induced velocity variations
   - Calculate power required for different flight conditions

- Validate with published UH-60 data
- Investigate effects of twist, taper, and airfoil selection

2. **Vortex Wake Simulation Project**
   - Implement prescribed wake model for hovering rotor
   - Visualize wake geometry and induced velocities
   - Extend to forward flight wake modeling
   - Compare with momentum theory results
   - Analyze wake aging and contraction effects
3. **Helicopter Performance & Mission Analysis**
   - Construct power required curves for given helicopter
   - Determine hover ceiling and service ceiling
   - Calculate maximum range and endurance
   - Perform mission analysis for specific operational profile
4. **Stability & Control Analysis**
   - Extract stability derivatives from flight test data
   - Simulate dynamic response to control inputs
   - Analyze coupled longitudinal-lateral modes
   - Evaluate handling qualities using ADS-33 criteria
   - Design stability augmentation system
5. **Advanced Configuration Design (Capstone)**
   - Option A: Design compound helicopter for high-speed mission
   - Option B: Optimize tiltrotor for urban air mobility application
   - Option C: Develop coaxial UAV for surveillance mission
6. **Requirements:**
   - Complete aerodynamic analysis
   - Performance prediction across flight envelope
   - Stability and control assessment
   - Comparison with conventional configuration
   - Technical report with recommendations