MIT ART, DESIGN AND TECHNOLOGY UNIVERSITY, PUNE

SCHOOL OF ENGINEERING AND SCIENCES PUNE

STRUCTURE and SYLLABUS

FOR

M. Tech. Aerospace Engineering

(Specialisation in Aerodynamics)

(76 Credits)

UNDER FACULTY OF ENGINEERING & SCIENCES

w.e.f. 2025-2026

MIT ADT University
Aerospace Engineering Department
M. Tech Aerospace Engineering
Specialisation: Aerodynamics
2025-26 Pattern

Semester I

Course Code	Course Name	Hours/week				Maximum Marks			Assessment
		L	T	P	C	CA	FE	Total	
25MTAS101R	Advanced Aerodynamics & Flow Physics	3		02	4	50	50	100	Open Book
25MTAS102R	Aerospace Propulsion Systems	3	--	--	3	50	50	100	Closed Book Exam
25MTAS103R	Computational Fluid Dynamics	3	--	--	3	50	50	100	Closed Book Exam
25MTAS104R	Data-driven Aerospace Engineering	3	--	--	3	50	50	100	Closed Book Exam
25MTAS105R	Advanced Research Techniques & Ethics	3	--	--	3	50	50	100	Jury-based evaluation
25MTAS206R	Technical Seminar-I	--	--	4	2	50	50	100	Jury-based evaluation
25MTAS107R	Computational Fluid Dynamics Lab	--	--	4	2	50	50	100	Laboratory/Practical Exams
25MTAS108R	Introduction to Aerospace Engineering	3	--	--	--	--	--	--	Audit
	Total	**18**	**00**	**10**	**20**	**350**	**350**	**700**	

Semester II

Course Code	Course Name	Hours/week				Maximum Marks			Assessment
		L	T	P	C	CA	FE	Total	
25MTAS201R	Turbulence Modelling & Simulation	3	--	--	3	50	50	100	Open Book
25MTAS202R	High-Speed Aerodynamics	3	--	02	4	50	50	100	Closed Book Exam
25MTAS203R	Numerical Methods & High-Performance Computing	3	--	02	4	50	50	100	Closed Book Exam
21MTAS104R	Engineering Economics & Financial Decision-Making	2	--		2	50	50	100	Closed Book Exam
25MTAS--	Elective-I	3	-		3	50	50	100	Open Book Exam

25MTAS205R	Advanced Aerodynamic Simulation Lab	--	--	4	2	50	50	100	Laboratory/Practical Exams
25MTAS206R	Mini Project	--	--	4	2	50	50	100	Jury-based evaluation
	Total	**14**	**00**	**12**	**20**	**350**	**350**	**700**	

Specialisation (Aerodynamics)

Elective-I

Course Code	Course Name	Hours/week				Maximum Marks		
		L	T	P	C	CA	FE	Total
25MTAS211R	Aerodynamic Design Optimization and Inverse Methods	3	-	--	3	50	50	100
25MTAS212R	Unsteady Aerodynamics & Aeroelasticity							

Semester III

Course Code	Course Name	Hours/week				Maximum Marks			Assessmen t
		L	T	P	C	CA	FE	Total	
25MTAS--	Elective-II	3	--	--	3	50	50	100	Open Book Exam
25MTAS301R	Advanced Research Methodologies and Scientific Communication	3	--	--	3	100	--	100	Case Study
25MTAS302R	Technical Seminar-II	--	--	4	2	50	50	100	Jury-based evaluation
25MTAS303R	Dissertation Phase -I	--	--	16	08	50	50	100	Jury-based evaluation
	Total	**06**	**00**	**20**	**16**	**250**	**150**	**400**	

Specialisation (Aerodynamics)

Elective-II

25MTAS321R	Advanced Boundary Layer Theory	3	-	--	3	50	50	100
25MTAS322R	Rotary Wing Aerodynamics							

Semester IV

Course Code	Course Name	Hours/week				Maximum Marks			Assessment
		L	T	P	C	CA	FE	Total	
25MTAS401R	Dissertation Phase-II	--	--	32	16	100	200	300	Jury-based evaluation
	Total	**00**	**00**	**32**	**16**	**100**	**200**	**300**	

SEMESTER – I

Course Code	Course Title				Category
25MTAD101R	**Advanced Aerodynamics & Flow Physics**				
Contact Hours per Week			**CA**	**FE**	**Credits**
L	**T**	**D/P**			
3	**0**	**02**	**50**	**50**	**4**

Prerequisite: Undergraduate Aerodynamics & Fluid Mechanics; Mathematical Foundations

Course Objectives:

1. To make students apply the knowledge in order to measure the lift and drag characteristics of an aerodynamic body and potential flow theory in order to measure the lift and drag characteristics for an inviscid incompressible flow
2. To make students analyze and measure the lift and drag characteristics of an airfoil using thin airfoil theory.
3. To Make students apply the knowledge of Prandtl's Classical Lifting-Line Theory to measure the lift and drag characteristics of a wing.
4. Learn the different Regimes of aircraft and performance requirements at different atmospheric conditions. Evaluate the equations of motion for an airplane
5. Estimate the time to climb and descent and gives the relation between rate of climb and descent and time to climb and descent at different altitudes

Course Outcome:

By the end of this course, students will be able to:

1. CO1: Summarize the governing equations of fluid flow, apply potential-flow theory, and classify aerodynamic flows for advanced applications.
2. CO2: Evaluate laminar and turbulent boundary-layer behavior, including methods for separation control and drag reduction.
3. CO3: Analyze turbulent flow physics, shear-layer development, and basic turbulence modeling approaches relevant to aerodynamic design.
4. CO4: Interpret compressible flow phenomena (shocks, expansions, transonic drag divergence) and assess shock–boundary layer interactions.
5. CO5: Discuss modern flow-control strategies, unsteady aerodynamics, and cutting-edge developments in flow physics, relating them to CFD validation and verification.

COURSE CONTENTS

Unit 1: Governing Equations & Inviscid Flow Fundamentals (9 Hours)

Navier–Stokes equations (inviscid vs. viscous); Potential Flow Theory (sources, sinks, doublets, vortex flow); Airfoil Theory (thin airfoil recap, vortex sheet); Flow Classification: Subsonic, transonic, supersonic regimes; Introduction to Panel Methods.

Unit 2: Boundary Layers & Viscous Flow (9 Hours)

Prandtl's Boundary-Layer Theory; Laminar vs. Turbulent boundary layers (Blasius solution, friction laws); Boundary-Layer Separation & Control Techniques; Approximate Integral Methods; Basic Turbulent Flow in Wall-Bounded Domains

Unit 3: Turbulent Flow & Shear Layers (9 Hours)

Reynolds Decomposition & RANS equations; Free Shear Layers (jets, wakes, mixing layers); Turbulence Energy Cascade & Kolmogorov Scales (conceptual); High-Lift Systems & Their Impact on Turbulent Flow; Introduction to Turbulence Modeling (algebraic, one-/two-equation)

Unit 4: Compressible Aerodynamics & Shock–Boundary Layer Interactions (9 Hours)

Fundamentals of Compressible Flow (Mach, stagnation properties); Normal & Oblique Shocks, Expansion Waves; Shock–Boundary Layer Interaction, Transonic Flows; Drag-Divergence, Area Rule; High-Speed Airfoil & Wing Design

Unit 5: Modern Flow Physics & Applications (9 Hours)

Flow Transition: Laminar-to-Turbulent (Tollmien–Schlichting waves); Flow Control (active & passive), Drag Reduction Techniques; Unsteady Aerodynamics: Vortex Shedding, Dynamic Stall; Bio-Inspired Flows, Morphing Surfaces, Novel High-Lift Concepts; CFD Validation & Verification for Advanced Flows.

Text Books

1. J. D. Anderson, Fundamentals of Aerodynamics, 6th ed., McGraw-Hill.
2. H. Schlichting and K. Gersten, Boundary-Layer Theory, 9th ed., Springer.
3. J. D. Anderson, Modern Compressible Flow: With Historical Perspective, 3rd ed., McGraw-Hill.

Reference Books

1. T. J. Chung, Computational Fluid Dynamics, 2nd ed., Cambridge University Press.
2. E. L. Houghton and P. W. Carpenter, Aerodynamics for Engineering Students, 7th ed., Butterworth-Heinemann.
3. P. Bradshaw, An Introduction to Turbulence and its Measurement, Pergamon Press.
4. Select AIAA Journal/Conference Papers for recent developments in flow control, unsteady aerodynamics, and advanced CFD validations.

Course Code	Course Title			Category		
25MTAD102R	**Aerospace Propulsion Systems**			DCC		
Contact Hours per Week			**CA**	**FE**	**Credits**	
L	**T**	**D/P**				
3	**0**	**0**	**50**	**50**	**3**	

Prerequisite: Thermodynamics; Fluid Mechanics.

Course Objectives:

The primary purpose of this course is to:

1. **Establish Aero-Propulsion Foundations:** Provide a robust theoretical base on gas turbine engines and chemical rocket propulsion, highlighting the aerodynamic factors influencing performance.
2. **Integrate CFD & Turbomachinery Analysis:** Illustrate how computational fluid dynamics applies to the design and optimization of propulsion components such as compressors, turbines, nozzles, and combustion chambers.
3. **Link Combustion & Flow Physics:** Explain the interplay between chemical reactions, fuel–oxidizer mixing, and flow expansions in both liquid and solid rocket propulsion systems.
4. **Discuss Advanced Propulsion Scenarios:** Explore contemporary and emerging propulsion concepts (scramjets, hybrid rockets, combined-cycle engines), emphasizing the aerodynamic constraints and design challenges.
5. **Reinforce Practical Industry Skills:** Strengthen students' ability to tackle real-world propulsion problems, considering both thermal management and flow stability, enabling them to innovate in aero-engine and rocket design.

Course Outcomes:

By the end of this course, students will be able to:

1. CO1: Analyze various air-breathing engines (piston, turboprop, turbojet, turbofan), identifying the aerodynamic and thermodynamic principles governing thrust and efficiency.
2. CO2: Apply CFD strategies to turbomachinery (e.g., compressors, turbines), evaluating blade loading, stall/surge phenomena, and design optimizations.
3. CO3: Explain the fundamentals of rocket propulsion (solid, liquid), including nozzle expansions, staging, and performance parameters, while identifying critical aerodynamic interactions.
4. CO4: Assess the impact of grain geometry and injector design on flow fields and combustion stability in solid and liquid rocket engines using numerical simulations.
5. CO5: Discuss advanced propulsion concepts (hybrid rockets, scramjets, combined-cycle engines), articulating the flow physics and CFD-based approaches crucial to design and performance evaluation.

COURSE CONTENT

Unit 1: Fundamentals of Air-Breathing Engines (9 Hours)

Overview of propulsion systems in aerospace (piston, turboprop, turbojet, turbofan); Thrust equation & performance parameters (TSFC, overall efficiency); Aerodynamic aspects: Inlet flow physics, subsonic vs. supersonic inlets, boundary-layer control; Thrust augmentation techniques: Afterburners, mixing, variable nozzles; Cycle analysis (Brayton cycle, parametric variation) for advanced designs.

Unit 2: Turbomachinery Aerodynamics & CFD (9 Hours)

Compressor & turbine blade aerodynamics (2D/3D flow, loading distributions); Cascade analysis, secondary flows, tip leakage, stall/surge phenomena; CFD methodologies for turbomachinery (grid generation, turbulence models); Performance maps, matching of compressor–turbine, stall margin, bleed flow; Case studies: HPC techniques in turbomachinery design & optimization

Unit 3: Chemical Rocket Propulsion & Nozzle Flows (9 Hours)

Basics of rocket propulsion: Tsiolkovsky rocket equation, staging fundamentals (brief); Nozzle flow: Conical vs. bell nozzles, under/over expansion, flow separation; Combustion fundamentals in rocket chambers (fuel–oxidizer mixing); CFD approach for rocket nozzles: supersonic expansions, contour optimization, shock–boundary layer interactions; Performance parameters: Characteristic velocity, specific impulse, thrust coefficient.

Unit 4: Solid & Liquid Propulsion Systems – Aerodynamic Considerations (9 Hours)

Solid propulsion: Grain configurations, burn rate, port geometry effects on flow fields and thrust stability; Liquid propulsion: Injectors (swirl, pintle, showerhead), feed systems, turbopumps, film cooling; Cooling and thermal management (heat flux distribution, film/regenerative cooling); Use of numerical simulations for chamber/injector flow, chemical kinetics, multi-phase flows; Propellant selection from an aerodynamic and thermal viewpoint.

Unit 5: Advanced & Emerging Propulsion Concepts (9 Hours)

Hybrid rocket systems: Regression rate, swirl injection, slurries/gelled propellants; Hypersonic air-breathing (scramjets, dual-mode ramjets): Combustor–inlet interactions, isolators, shock trains; Combined-cycle engines (TBCC, RBCC) and aerodynamic design constraints; Electrically assisted or plasma propulsion (brief overview); Advanced nozzle designs (aerospike, expansion–deflection nozzles) and CFD-based design optimization.

Textbooks

1. Sutton G.P. and Biblarz O., *Rocket Propulsion Elements*, 7th ed., Wiley India Pvt. Ltd., 2003.
2. Hill P.G. and Peterson C. R., *Mechanics and Thermodynamics of Propulsion*, 2nd ed., Pearson Education, 1999.
3. Mattingly J.D., *Elements of Propulsion: Gas Turbines and Rockets*, 2nd ed., AIAA Education, 2016.

Reference Books

1. Mukunda H.S., *Understanding Aerospace Chemical Propulsion*, 2nd ed., IK International, 2017.
2. Ramamurthi K., *Rocket Propulsion*, 1st ed., Macmillan India, 2010.
3. Mishra D.P., *Fundamentals of Rocket Propulsion*, 1st ed., CRC Press, 2017.
4. Sahoo N., *Gas Turbine Technology*, McGraw-Hill Education, [Year not specified].
5. Contemporary CFD and Journal Articles (e.g., AIAA, ASME, etc.) for advanced turbomachinery, nozzle design, and high-speed propulsion research.

Course Code	Course Title			Category	
25MTAD103R	**Computational Fluid Dynamics**			DCC	
Contact Hours per Week			CA	FE	Credits
L	T	D/P			
3	0	0	50	50	3
Prerequisite:					

Course Objectives:

The primary purpose of this course is to:

1. **Introduce** the fundamental conservation laws (continuity and Navier–Stokes equations) and their physical significance in aerodynamic problems.
2. **Develop** skills in discretizing governing equations using finite volume and finite difference methods.
3. **Implement** boundary condition treatments, and study stability and convergence of numerical solutions.
4. **Provide** practical exposure to setting up and solving CFD problems using commercial or open-source CFD codes.
5. **Bridge** theoretical knowledge with real-world applications through validation and verification techniques.

Course Outcomes:

After learning this course, students shall be able to:

1. **CO1**: **Formulate** CFD problems by correctly establishing the governing equations and physical models.
2. **CO2**: **Discretize** the governing equations using appropriate numerical techniques (finite volume/difference methods) for various flow conditions.
3. **CO3**: **Implement** and apply suitable boundary conditions and analyze numerical stability and convergence of CFD solutions.
4. **CO4**: **Set up** and solve basic aerodynamic problems using CFD software, interpreting the simulation results effectively.
5. **CO5**: **Validate** CFD outcomes through comparison with analytical or experimental data, ensuring the reliability of numerical predictions.

COURSE CONTENT

Unit 1: Governing Equations & Physical Modeling (9 Hours)

Introduction to the conservation laws: the continuity equation and the Navier–Stokes equations (both incompressible and compressible forms); Constitutive relations and fluid properties; Dimensional analysis and scaling for CFD applications; Overview of simplified models (e.g., Euler equations for inviscid flows).

Unit 2: Discretization Methods (9 Hours)

Numerical discretization techniques: finite difference and finite volume methods; Spatial discretization of convective and diffusive fluxes; Mesh generation fundamentals and evaluation of grid quality; Treatment of boundary fluxes and the concept of upwinding

Unit 3: Boundary Conditions & Numerical Stability (9 Hours)

Types of boundary conditions (Dirichlet, Neumann, and mixed) and their implementation in CFD; Setting up physical boundary conditions for internal and external flows; Stability analysis and convergence criteria, including the CFL condition; Techniques for residual monitoring and error estimation.

Unit 4: Time Integration & Convergence (9 Hours)

Time-stepping methods: explicit, implicit, and semi-implicit schemes; Stability criteria for transient simulations (CFL condition, time step selection); Convergence analysis and residual evaluation Error analysis and validation of numerical results.

Unit 5: Practical CFD Applications & Solver Setup (9 Hours)

Pre-processing: Geometry creation and meshing for aerodynamic problems; Solver setup: Implementation of boundary conditions, solver parameter selection; Post-processing: Data extraction, visualization, and validation of CFD results; Case studies: Solving basic aerodynamic flows (e.g., flow over an airfoil, channel flow); Verification & validation procedures in CFD.

Textbook

1. J. Tu, G. H. Yeoh, and C. Liu, *Computational Fluid Dynamics: A Practical Approach*, 3rd ed., Butterworth-Heinemann, 2018.

Reference Book

1. H. K. Versteeg and W. Malalasekera, *An Introduction to Computational Fluid Dynamics: The Finite Volume Method*, 2nd ed., Pearson, 2007.

Course Code	Course Title				Category
25MTAD104R	Data-driven Aerospace Engineering				
Contact Hours per Week			CA	FE	Credits
L	T	D/P			
3	-	-	50	50	3

Prerequisite: Basic Programming Skills; Fundamentals of Mathematics; Introductory Knowledge of Aerospace Engineering.

Course Objectives:

1. **Introduce AI/ML Fundamentals**: Provide a solid overview of Artificial Intelligence, Machine Learning, and Deep Learning, especially in the context of aerospace applications.
2. **Develop Practical Skills**: Enable students to use Python/Jupyter Notebook for data analysis and model building.
3. **Explore Core Algorithms**: Familiarize students with essential ML algorithms and how they can be adapted to aerospace problems.
4. **Integrate Theory and Practice**: Demonstrate real-world aerospace case studies where AI/ML solutions can offer tangible benefits.
5. **Promote Industry-Relevant Expertise**: Equip students with the knowledge and skills that align with current industry needs in the aerospace sector.

Course outcome (CO):

By the end of this course, students will be able to:

1. **CO1:** Explain the evolution, importance, and industry demand for AI/ML in aerospace engineering. (Understanding – Bloom's Level 2)
2. **CO2:** Identify and apply fundamental ML algorithms for basic classification, regression, and clustering tasks. (Applying – Bloom's Level 3)
3. **CO3:** Demonstrate proficiency in setting up programming environments (Jupyter Notebook) and coding essential AI/ML workflows. (Applying – Bloom's Level 3)
4. **CO4:** Implement and analyse AI/ML models to address typical aerospace engineering challenges (e.g., fault detection, performance prediction). (Analyzing – Bloom's Level 4)
5. **CO5:** Evaluate the performance and limitations of AI/ML solutions, proposing improvements for aerospace-specific applications. (Evaluating – Bloom's Level 5)

Course Content

Unit 1: Introduction to AI/ML in Aerospace (9 Hours)

Milestones in AI development, early machine learning successes; Current aerospace industry trends: predictive maintenance, design optimization, autonomous systems; Role of AI/ML in reducing costs, improving safety, and accelerating innovation; Distinctions between AI, ML, and DL; Overview of supervised vs. unsupervised learning, reinforcement learning (brief mention); Examples from leading aerospace companies (e.g., Boeing, Airbus, SpaceX)

Unit 2: Key Machine Learning Algorithms (9 Hours)

Linear Regression / Logistic Regression; Decision Trees / Random Forests; Support Vector Machines (SVM); K-Means Clustering; Basic Neural Networks (intro to feed-forward architecture); Bias-Variance trade-off, overfitting vs. underfitting; Performance metrics (accuracy, precision, recall, F1-score); Data preparation, feature engineering, scaling; Hyperparameter tuning (grid search, cross-validation)

Unit 3: Introduction to Programming with Jupyter Notebook (9 Hours)

Installing Anaconda, creating virtual environments, accessing Jupyter Notebook; Basic syntax, data types, control structures; Libraries: NumPy, Pandas, Matplotlib, scikit-learn (high-level introduction); Reading/writing data, cleaning and preprocessing; Plotting libraries (Matplotlib or Seaborn); Simple dataset exploration (e.g., reading CSV, basic statistics, plotting)

Unit 4: Coding ML Models in Jupyter Notebook (9 Hours)

Step-by-step guides to coding the chosen 5 algorithms from Unit 2 using scikit-learn or TensorFlow/Keras (basic introduction); Train/test splits, cross-validation, confusion matrix (for classification); Debugging, troubleshooting common errors, performance optimization; Real-time coding with example datasets (e.g., classification of aircraft types, regression on flight performance data)

Unit 5: Aerospace Case Studies & Applications (9 Hours)

Predictive Maintenance of aircraft components (fault detection); Flight Path Optimization (basic scenario modeling); Wind Tunnel Data Analysis (drag/lift prediction); Autonomous Aerial Vehicles (simplified control strategy); Satellite Image Analysis (basic object detection or cloud cover classification); Planning an end-to-end AI/ML project in aerospace: data sources, project scoping, resource requirements

Text Books

1. Aurélien Géron, *Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow*, 2nd ed., O’Reilly Media, 2019.
2. Sebastian Raschka and Vahid Mirjalili, *Python Machine Learning*, 3rd ed., Packt Publishing, 2019.

Reference Books

1. François Chollet, *Deep Learning with Python*, 2nd ed., Manning Publications, 2021.
2. Steven L. Brunton and J. Nathan Kutz, *Data-Driven Science and Engineering: Machine Learning, Dynamical Systems, and Control*, Cambridge University Press, 2019.

Course Code	Course Title				Category
25MTAD105R	Advanced Research Techniques & Ethics				RM
Contact Hours per Week			CA	FE	Credits
L	T	D/P			
3	0	0	50	50	3

Prerequisite:
Basic Understanding of Probability and Statistics; General Knowledge of Scientific Inquiry.

Course Objectives:
The primary purpose of this course is to:

1. **Introduce Research Methodology Basics**: Provide a foundational understanding of what constitutes a research topic, how to conduct a literature review, and the overall research process.
2. **Develop Data Collection and Sampling Skills**: Equip students with the knowledge to design surveys and experiments effectively, distinguishing between primary and secondary data sources.
3. **Apply Statistical and Analytical Methods**: Teach students to use statistical modeling, time-series analysis, and multivariate methods for data interpretation.
4. **Explore Evolutionary Algorithms and Optimization**: Familiarize students with genetic algorithms, neural network-based optimization, and other advanced tools for research.
5. **Enable Effective Research Reporting**: Guide students in structuring and writing clear, comprehensive research reports, covering layout and ethical considerations.

Course Outcomes:
After learning this course, students shall be able to:

1. **CO1**: **Identify** the key components of research methodology, framing appropriate research questions and objectives.
2. **CO2**: **Design** suitable data collection methods, including questionnaires, surveys, and sampling strategies, and **evaluate** their merits and limitations.
3. **CO3**: **Apply** statistical tools and time-series analysis to interpret data, drawing meaningful inferences for research studies.
4. **CO4**: **Implement** evolutionary algorithms and advanced optimization methods (genetic algorithms, simulated annealing, etc.) for complex research problems.
5. **CO5**: **Compose** well-structured research reports, demonstrating ethical standards and clear scientific communication.

COURSE CONTENT

Unit 1: Introduction to Research Methods (9 Hours)

What is research methodology?, What constitute a research topic? What is literature review?, Research process, Classification of research, Research ethics, Objectives of research, Motivation in research, Criteria of good research.

Unit-2: Data collection and sampling design (9 Hours)

Sources of Data: Primary Data, Secondary Data: Procedure Questionnaire – Survey and Experiments – Design of Survey and Experiments – Sampling Merits and Demerits – Control Observations – Procedures – Sampling Errors.

Unit-3: Statistical Modelling and Analysis, Time Series Analysis (9 Hours)

Probability Distributions, Fundamentals of Statistical Analysis and Interference, Multivariate methods, Concepts of Correlation and Regression, Time Series and Spectral Analysis.

Unit-4: Evolutionary algorithms (9 Hours)

Introduction to evolutionary algorithms – Fundamental of Genetic Algorithms, Simulated Annealing, Neural Network based optimisation, Optimization of fuzzy systems.

Unit-5: Research report (9 Hours)

Structure and Components of Research Report, Types of Report, Layout of Research Report, Mechanism of writing a research report.

Text Books:

1. **R. Kumar**, *Research Methodology: A Step-by-Step Guide for Beginners*, 4th ed., London, U.K.: SAGE Publications Ltd, 2014.
2. **C. R. Kothari**, *Research Methodology: Methods and Techniques*, 2nd ed., New Delhi, India: NEW AGE, 2014.
3. **P. Pruzan**, *Research Methodology: The Aims, Practices and Ethics of Science*, 1st ed., Cham, Switzerland: Springer, 2016.

Reference Books:

1. **P. Engelbrecht**, *Computational Intelligence: An Introduction*, 2nd ed., West Sussex, U.K., Wiley-Blackwell, 2007.
2. **J. Hayter**, *Probability and Statistics for Engineers and Scientists*, 4th ed., Boston, MA, USA: CENGAGE Learning Custom Publishing, 2011.
3. **C. Beins and M. A. McCarthy**, *Research Methods and Statistics*, Boston, MA, USA: Pearson, 2011.
4. **Neville**, *The Complete Guide to Referencing and Avoiding Plagiarism*, Maidenhead, U.K.: Open University Press, 2007.
5. **Kumar**, *Research Methods for Successful PhD*, River Publishers Series in Innovation and Change in Education — Cross Cultural Perspective, 2017.
6. **M. van Dongen**, *LaTeX and Friends*, Heidelberg, Germany: Springer, 2012.

Course Code	Course Title					Category
25MTAD106R	TECHNICAL SEMINAR -I					Program Core
Contact Hours per Week			CA	FE	Credits	
L	T	D/P				
0	0	4	50	50	2	

Prerequisite: A fundamental understanding of the core concepts in the relevant subject area, with the ability to read and interpret technical papers and research articles.

Course Objectives

The primary purpose of this course is to:

1. **Identify and Compare Technical & Practical Issues**: Enable students to explore advanced or emerging topics in their area of specialisation.
2. **Develop Scholarly Skills**: Encourage creating an annotated bibliography from research papers, demonstrating thorough literature investigation.
3. **Refine Technical Writing & Critical Thinking**: Train students to prepare well-structured reports and technical documents.
4. **Enhance Presentation Skills**: Improve competence in describing, interpreting, and analysing technical findings, culminating in effective oral presentations.

Course Outcomes

By the end of the course, students will be able to:

1. Establish Motivation for a chosen topic and develop a structured thought process for technical communication.
2. Organize a Detailed Literature Survey and synthesise findings in a coherent document referencing significant technical publications.
3. Analyze and Comprehend proof-of-concept data or theoretical underpinnings related to the selected topic.
4. Deliver Effective Presentations that showcase clarity of thought, improved soft skills, and command of the subject.
5. Utilize Modern Tools (e.g., LaTeX) for preparing high-quality technical reports, thereby embracing recent technology in document creation.

Course Content

During Technical Seminar - I, students shall:

1. Select a Research Topic: Identify an advanced or emerging area relevant to their specialization.
2. Conduct a Literature Review: Summarize and critique research papers, focusing on existing methodologies, findings, and gaps in knowledge.
3. Perform Data Collection & Analysis: Gather information from published works, compare methodologies, and draw inferences.
4. Prepare a Seminar Report: Document objectives, literature findings, methods (if any data were collected), and conclusions in a structured format.
5. Deliver a Presentation: Present the summarised work, highlighting the key concepts, contributions, and future scope.

<table>
<tr><td colspan="2">Course Code</td><td colspan="3">Course Title</td><td>Category</td></tr>
<tr><td colspan="2">25MTAD107R</td><td colspan="3">Computational Fluid Dynamics Lab</td><td></td></tr>
<tr><td colspan="3">Contact Hours per Week</td><td rowspan="2">CA</td><td rowspan="2">FE</td><td rowspan="2">Credits</td></tr>
<tr><td>L</td><td>T</td><td>D/P</td></tr>
<tr><td>-</td><td>-</td><td>4</td><td>50</td><td>50</td><td>2</td></tr>
<tr><td colspan="6">Prerequisite:
Basic Fluid Mechanics; Fundamentals of Aerodynamics; Introductory Programming/Software Skills.</td></tr>
<tr><td colspan="6">Course Objectives:
The primary purpose of this course is to:
1. Introduce ANSYS Workbench and establish a structured approach to CFD workflows (geometry, mesh, setup, solve, post-process).
2. Familiarize Students with Simple Aerodynamic Simulations such as laminar flow over basic geometries and low-angle-of-attack airfoils.
3. Provide Experimental Insight using wind tunnel testing to measure lift, drag, and pressure distributions for fundamental comparison with CFD results.</td></tr>
<tr><td colspan="6">Course Outcomes
By the end of the course, students will be able to:
1. CO1: Operate ANSYS Workbench and set up simple CFD cases, demonstrating basic software proficiency.
2. CO2: Apply foundational concepts of laminar flow to internal (pipe/duct) and simple external geometries (airfoils, cylinders).
3. CO3: Compare CFD results with analytical or known solutions, highlighting the significance of mesh quality and boundary conditions.
4. CO4: Conduct basic wind tunnel experiments, measuring aerodynamic forces and correlating them with simulation outputs.
5. CO5: Report and interpret data from both numerical and experimental methods, reinforcing the fundamentals of aerodynamics.</td></tr>
</table>

LIST OF EXPERIMENTS

Any eight experiments should be selected from the list provided. Experiments 9 and 10 are optional for B.E./B.Tech Aerospace/Aeronautical students, but mandatory for students from other disciplines.

1. **Orientation & ANSYS Workbench GUI Familiarization**
   Students learn how to navigate ANSYS Workbench, create basic geometries, and set up simple flow simulations. This exercise lays the groundwork for the overall CFD workflow, emphasizing project organization, interface familiarity, and essential solver settings.
2. **2D Laminar Pipe Flow: Introduction to Internal Flows**
   A 2D or axisymmetric pipe model is created and meshed to study velocity profiles in laminar flow. The simulation results are compared with the Hagen–Poiseuille analytical solution, reinforcing fundamental internal flow concepts and illustrating mesh-refinement practices.
3. **2D Backward-Facing Step: Basic Flow Separation**
   Students investigate a flow domain featuring a backward-facing step to observe separation and reattachment phenomena. This lab highlights the importance of boundary condition setup, mesh distribution near the step, and the physics of recirculating flows.

4. **2D Flow Over a Cylinder (Low Re): Laminar Wake Analysis**
   At a moderate Reynolds number (e.g., Re ~100), the cylinder flow remains laminar. Students generate and refine meshes, then visualize the steady wake region, measuring drag coefficients and discussing how geometry and Reynolds number influence flow patterns.
5. **2D Flow Over a Flat Plate: Boundary-Layer Formation**
   By simulating flow over a flat plate at low Reynolds numbers, students explore boundary-layer buildup. Velocity profiles at multiple x-positions are extracted and compared against the Blasius solution, emphasizing boundary-layer theory and mesh refinement near walls.
6. **2D Laminar Flow Over a Simple Airfoil (Low Angle of Attack)**
   A basic airfoil geometry is imported or generated. The simulation focuses on lift and drag predictions under laminar conditions at small angles of attack, introducing students to aerodynamic coefficients and the significance of correct inlet, outlet, and far-field boundaries.
7. **2D Mixing Elbow or T-Junction (Laminar) for Flow Distribution**
   Two inflow streams with different velocities or fluid properties are combined in a mixing region. Students learn about scalar transport, pressure drop, and streamline visualization in an internal flow system that requires careful selection of boundary conditions.
8. **Basic 3D Geometry Exploration & Meshing in ANSYS**
   Students transition from 2D to 3D by setting up a simple geometry (e.g., a short 3D duct or cavity). The lab covers creating a 3D mesh, setting appropriate boundary conditions, and discussing the differences in solver complexity and computational costs.
9. **Wind Tunnel Experiment 1: Lift & Drag Measurement on a Symmetrical Airfoil**
   Non-Aerospace students perform a subsonic wind tunnel test to measure lift and drag at various angles of attack, while Aerospace students may opt out if already experienced. Data is compared with CFD predictions from earlier labs, reinforcing theoretical-experimental agreement.
10. **Wind Tunnel Experiment 2: Pressure Distribution & Flow Visualization over an Airfoil**
    Students measure surface pressure via taps on an airfoil and use smoke/tufts for flow visualization. The resulting pressure coefficients and flow patterns are cross-checked against CFD results, emphasizing the connection between experimental measurements and numerical simulations.

Text Book

1. Tu, J., Yeoh, G. H., & Liu, C., *Computational Fluid Dynamics: A Practical Approach*, 3rd ed., Butterworth-Heinemann, 2018.

Reference Books / Notes

1. Versteeg, H. K. & Malalasekera, W., *An Introduction to Computational Fluid Dynamics: The Finite Volume Method*, 2nd ed., Pearson, 2007.
2. Ansys Software Tutorial: Introduction to Ansys Fluent #1 – First CFD Simulation, Mitchell Boots, University of Newcastle, edited by the Ansys Academic Development Team, *PDF Link*.

Additional Video/Online Resource

1. Cornell University FLUENT Learning Modules
   (A collection of step-by-step tutorials and video guides illustrating how to set up and solve fluid flow problems in ANSYS Fluent.)

<table>
<tr><th>Course Code</th><th colspan="4">Course Title</th><th>Category</th></tr>
<tr><td>25MTAD108R</td><td colspan="4">Introduction to Aerospace Engineering</td><td></td></tr>
<tr><td colspan="3">Contact Hours per Week</td><td rowspan="2">CA</td><td rowspan="2">FE</td><td rowspan="2">Credits</td></tr>
<tr><td>L</td><td>T</td><td>D/P</td></tr>
<tr><td>3</td><td>-</td><td>-</td><td>50</td><td>50</td><td>0</td></tr>
</table>

Prerequisite: Basic Physics and Mathematics.

Course Objectives:

The primary purpose of this course is to:

1. **Understand Historical Evolution**: Familiarize students with the early developments and key milestones in aerospace engineering, from early flight to modern spacecraft.
2. **Grasp Fundamental Aerodynamics**: Introduce the physics of fluid flow, airfoil theory, and fundamental forces acting on aircraft.
3. **Explore Propulsion Systems**: Examine various propulsion methods, including jet and rocket engines, and emerging green/electric aircraft propulsion.
4. **Examine Aerospace Structures & Materials**: Study the design, stress analysis, and material selection for aerospace applications, including advanced manufacturing techniques.
5. **Introduce Instruments & Navigation**: Provide insight into measurement techniques, navigation principles, and data acquisition in modern flight operations.

Course outcome (CO)

By the end of the course, students will be able to:

1. CO1: Describe the historical evolution of aerospace engineering and significant achievements in flight and space exploration.
2. CO2: Explain fundamental aerodynamic concepts, including lift, drag, and the effects of different flight regimes (subsonic, supersonic, and hypersonic).
3. CO3: Compare various propulsion systems (piston, turbojets, turbofans, ramjets, scramjets) and evaluate emerging technologies such as electric propulsion.
4. CO4: Analyze aerospace structures, recognizing key load-bearing configurations, material properties, and manufacturing processes.
5. CO5: Interpret instrument data and navigation principles in aviation and demonstrate understanding of basic UAV systems and their applications.

COURSE CONTENTS

Unit-1 HISTORICAL EVALUATION (9 Hours)

Introduction to Aerospace Engineering: Scope, Applications, and Historical Evolution, Overview of Aeronautics and Astronautics, Basic Aerodynamics: Properties of the Atmosphere, Standard Atmosphere, and Types of Flow, Fundamental Forces on an Aircraft: Lift, Drag, Thrust, and Weight, history of spaceflight, development of space vehicles, classification of duct jet propulsion, rocket propulsion, advance propulsion and applications.

Unit-2 BASIC AERODYNAMICS (9 Hours)

Anatomy of flight vehicles, components of airplanes and their function, Types of Aircraft: Subsonic, Supersonic, and Hypersonic Flight, bluff bodies v/s streamlined body, airfoil, NACA nomenclature . lift generation, significance of L/D ratio, aerodynamic forces, Basic Flight

Mechanics: Straight and Level Flight, Climbing, and Gliding, Stability and Control: Static and Dynamic Stability, Control Surfaces

Unit-3 PROPULSION (9 Hours)

Classification and essential features of propulsion, jet propulsion, Types of Aircraft Engines, Piston Engines, Turbojets, Turbofans, Ramjets, and Scramjets, Thrust Generation and Specific Fuel Consumption, general characteristics of rocket engines, theory of propulsion, elementary gas dynamics, Emerging Propulsion Technologies: Green Propulsion and Electric Aircraft

Unit-4 AEROSPACE STRUCTURES AND MATERIALS (9 Hours)

General types of construction and structural layout, Stress and Strain in Aerospace Structures, flight envelope and V-n diagrams, monocoque, semimonocoque, corrugated, sandwich structure, reinforced and honeycomb structures, geodesic construction, aerospace materials, metallic and non-metallic materials, use of aluminum alloy, titanium, stainless steel, composite and ceramic materials, Manufacturing Techniques: Additive Manufacturing and Composite Fabrication

Unit-5 INSTRUMENTS AND NAVIGATION (9 Hours)

Measurements in aerodynamics, flight structures, and flight control, principles of navigation, celestial, radio, and inertial navigation, Introduction to computer-based data acquisition. Introduction to basics of UAVs., their types, working and applications.

TEXT BOOKS

1. Anderson, J. D., "Introduction to Flight", McGraw-Hill, 2000.
2. John Fay, “ The Helicopter : History,Piloting and How it Flies ”, Sterling Book House, 2007.
3. Newman D, “Interactive Aerospace Engineering and Design”, McGraw-Hill, 1st Edition, 2002
4. Shevel, "Fundamentals of Flight", Prentice Hall, 1989.

REFERENCE BOOKS

1. Kermode, A. C., "Flight without Formulae", Pitman, 1970
2. Turner, M. J. L., “Rocket and Spacecraft Propulsion: Principles”, Practice and New Developments, Springer, 2009, 3rd Edition.

SEMESTER –II

Course Code	Course Title					Category
25MTAD201R	**Turbulence Modelling & Simulation**					**CFD**
Contact Hours per Week			**CA**	**FE**	**Credits**	
L	**T**	**D/P**				
3	**0**	**0**	**50**	**50**	**3**	
Prerequisite: Fluid Dynamics, Heat Transfer, Aerodynamics						

Course Objectives:

The primary purpose of this course is to:

1. **Introduce** the fundamental statistical description and physical concepts of turbulence.
2. **Develop** an understanding of various turbulence modeling approaches including RANS, LES, and DNS.
3. **Equip** students with practical skills in selecting and implementing appropriate turbulence models for different aerodynamic flows.
4. **Provide** guidelines for model validation, sensitivity analysis, and industrial CFD applications.
5. **Discuss** advanced and hybrid modeling techniques and emerging research trends in turbulence simulation.

Course Outcomes:

After learning this course, students will be able to:

1. **CO1**: **Summarize** the fundamental characteristics of turbulent flows and statistically describe turbulence using Reynolds decomposition and energy cascade concepts.
2. **CO2**: **Derive** and **apply** RANS equations and associated turbulence closure models (e.g., k-ε, k-ω, Spalart–Allmaras) to practical CFD problems.
3. **CO3**: **Implement** LES and understand the distinctions between LES and DNS, including subgrid-scale modeling.
4. **CO4**: **Evaluate** and **select** appropriate turbulence models based on flow conditions and grid resolution, using sensitivity analyses and industrial case studies.
5. **CO5**: **Discuss** advanced topics in hybrid turbulence modeling and emerging techniques, and critically review recent research trends in aerospace CFD applications.

COURSE CONTENT

Unit 1: Fundamentals of Turbulence and Statistical Description (9 Hours)

Introduction to turbulence: definition, characteristics, and significance in fluid flow; Reynolds decomposition and statistical description of turbulent flows; Energy cascade, turbulence scales, and Kolmogorov hypotheses' Turbulence intensity and isotropy; Overview of turbulence modeling approaches (brief mention of DNS, LES, and RANS).

Unit 2: RANS Modeling Approaches (9 Hours)

Derivation of Reynolds-Averaged Navier–Stokes (RANS) equations; The turbulence closure problem and the Boussinesq hypothesis; Overview of one-equation and two-equation models; Detailed study of standard turbulence models: k-ε, k-ω, and Spalart–Allmaras; Advantages, limitations, and practical considerations in model selection.

Unit 3: Large Eddy Simulation (LES) and DNS Overview (9 Hours)

Fundamentals of LES: filtering operations, subgrid-scale (SGS) models, and the Smagorinsky model; Comparison between LES and DNS: benefits and computational challenges; Overview of dynamic and advanced subgrid-scale models; Practical applications and limitations of LES and DNS in industrial CFD.

Unit 4: Practical Guidelines for Turbulence Model Selection (9 Hours)

Criteria for selecting turbulence models based on flow characteristics (e.g., high-speed, wall-bounded flows); Sensitivity analysis and grid resolution effects on turbulence simulation; Validation and verification methods for turbulence models; Industrial case studies illustrating model selection in aerospace CFD applications.

Unit 5: Advanced Topics in Turbulence Simulation (9 Hours)

Hybrid turbulence modeling approaches (e.g., RANS-LES, Detached Eddy Simulation (DES)); Scale-resolving simulations and emerging hybrid techniques; Limitations of classical turbulence models and recent advancements in the field; Future directions in turbulence research, with a focus on aerospace applications and CFD innovations.

Textbook

1. J. Tu, G. H. Yeoh, and C. Liu, *Computational Fluid Dynamics: A Practical Approach*, 3rd ed., Butterworth-Heinemann, 2018.

Reference Book

1. H. K. Versteeg and W. Malalasekera, *An Introduction to Computational Fluid Dynamics: The Finite Volume Method*, 2nd ed., Pearson, 2007.

Course Code	Course Title					Category
25MTAD202R	**High Speed Aerodynamics**					**DCC**
Contact Hours per Week			**CA**	**FE**		**Credits**
L	**T**	**D/P**				
3	**0**	**2**	**50**	**50**		**4**
Prerequisite: Fluid mechanics; Basic of compressible flow; Numerical methods						

Course Objectives:

The main purpose of this course is to:

1. **Introduce** the fundamental principles of compressible flow and the effects of high Mach numbers on aerodynamic performance.
2. **Examine** the behavior and properties of shock waves (normal, oblique, and expansion) and their impact on flow fields.
3. **Analyze** the complexities of transonic flows, including shock-induced boundary layer separation and drag divergence.
4. **Explore** the aerodynamic characteristics of supersonic and hypersonic regimes, including high-temperature and real-gas effects.
5. **Implement** modern CFD techniques to simulate high-speed flows, including shock-capturing methods, turbulence modeling for compressible regimes, and validation against analytical and experimental data.

Course Outcomes:

After learning this course, students shall be able to:

1. **CO1**: **Demonstrate** an in-depth understanding of compressible flow governing equations and the significance of Mach number in high-speed aerodynamics.
2. **CO2**: **Analyze** shock wave phenomena—including normal, oblique, and expansion waves—and predict their impact on aerodynamic performance.
3. **CO3**: **Evaluate** the characteristics of transonic flows and assess the effects of shock-induced boundary layer separation on aircraft performance.
4. **CO4**: **Characterize** supersonic and hypersonic flow behaviors, including shock–boundary layer interactions and real-gas effects, through both analytical and numerical methods.
5. **CO5**: **Implement** and **validate** CFD techniques for high-speed flows, applying appropriate shock-capturing schemes, turbulence models, and grid resolution strategies.

COURSE CONTENT

Unit 1: Fundamentals of Compressible Flow and Mach Number Effects (9 Hours)

Introduction to compressible flow: continuity, momentum, and energy equations in compressible form; Mach number, isentropic relations, and stagnation properties; Effects of compressibility on aerodynamic performance and flow behavior.

Unit 2: Shock Waves – Normal, Oblique, and Expansion (9 Hours)

Definition and properties of shock waves; Normal shock relations and oblique shock theory; Expansion fans and Prandtl–Meyer functions; Shock polars and flow separation in nozzles

Unit 3: Transonic Aerodynamics (9 Hours)

Characteristics of transonic flows: onset of shock waves and drag divergence; Critical Mach number and area rule concepts; Shock-induced boundary layer separation and its impact on aircraft performance.

Unit 4: Supersonic and Hypersonic Flow Phenomena (9 Hours)

Flow behavior in supersonic regimes: shock wave interactions, expansion waves, and pressure recovery; Hypersonic flow fundamentals: high-temperature effects, real-gas behavior; Shock–boundary layer interactions and their aerodynamic consequences.

Unit 5: CFD Techniques for High-Speed Flows and Shockwave-Boundary Layer Interactions (9 Hours)

Numerical methods for compressible CFD: shock-capturing schemes and discretization strategies; Implementation of boundary conditions and grid resolution considerations in high-speed flows; Turbulence modeling specific to compressible regimes; Verification and validation of CFD results through analytical and experimental comparisons.

Textbook

[1] J. D. Anderson, *Modern Compressible Flow: With Historical Perspective*, 3rd ed., McGraw-Hill, 2010.

Reference Book

[1] J. Tu, G. H. Yeoh, and C. Liu, *Computational Fluid Dynamics: The Basics with Applications*, 1st ed., Wiley, 2018.

Course Code	Course Title				Category
25MTAD203R	**Numerical Methods & High-Performance Computing**				**DCC**
Contact Hours per Week			**CA**	**FE**	**Credits**
L	**T**	**D/P**			
3	**0**	**2**	**50**	**50**	**4**

Prerequisite: Fluid mechanics, Aerodynamics, Calculus, Differential equations, Numerical methods and Programming skills.

Course Objectives:

The main purpose of this course is to:

1. **Introduce** advanced numerical algorithms used in CFD, emphasizing discretization techniques and error analysis.
2. **Develop** practical skills in implementing time-marching schemes and high-order methods for accurate aerodynamic simulations.
3. **Implement** parallel computing strategies, including domain decomposition and the use of MPI/OpenMP for large-scale CFD problems.
4. **Explore** GPU acceleration techniques to enhance simulation performance through CUDA/OpenCL programming.
5. **Establish** HPC best practices, focusing on code optimization, scalability, and industrial CFD applications in aerospace.

Course Outcomes:

After learning this course, students shall be able to:

1. **CO1: Formulate** discretized representations of the governing fluid dynamics equations for aerodynamic flows using advanced numerical methods.
2. **CO2: Implement** high-order time-marching schemes and analyze their accuracy, stability, and convergence characteristics.
3. **CO3: Develop** and **apply** parallel computing techniques (using MPI/OpenMP) to accelerate CFD simulations effectively.
4. **CO4: Utilize** GPU acceleration strategies to optimize CFD algorithms, demonstrating improved computational efficiency.
5. **CO5: Validate** and **optimize** large-scale industrial CFD simulations by applying HPC best practices and performance benchmarking.

COURSE CONTENT

Unit 1: Fundamentals of Numerical Methods for Aerodynamics (9 Hours)

Overview of CFD: Governing equations (Navier–Stokes, Euler) in compressible/incompressible flows; Discretization methods: Finite difference, finite volume, and finite element techniques; Numerical accuracy, stability, and convergence analysis (truncation error, numerical diffusion)

Unit 2: Advanced Numerical Algorithms (9 Hours)

Time-marching schemes: Explicit methods (e.g., Runge-Kutta) vs. Implicit methods (e.g., Crank-Nicolson); Trade-offs between accuracy, stability, and computational cost; High-order discretization techniques: Spectral methods and high-order finite differences.

Unit 3: Parallel Computing Techniques for CFD (9 Hours)

Overview of parallel computing paradigms: Shared vs. distributed memory architectures; Domain decomposition strategies for both structured and unstructured grids; Load balancing and communication overhead in parallel CFD; Implementation of parallel algorithms using MPI and OpenMP.

Unit 4: GPU Acceleration for CFD (9 Hours)

Fundamentals of GPU architectures and the basics of CUDA/OpenCL programming; Strategies for porting CFD algorithms to GPUs: Data parallelism and optimization techniques; Performance benchmarking: Comparing CPU and GPU implementations; Scalability and efficiency in high-speed simulations.

Unit 5: HPC Best Practices and Industrial CFD Applications (9 Hours)

Code optimization strategies for large-scale CFD: Memory usage, efficient data structures, and algorithmic enhancements; Scalability analysis and performance benchmarking on modern HPC systems (clusters, supercomputers, cloud computing); Tools for parallel debugging, profiling, and performance tuning; Industrial case studies on large-scale CFD simulations in aerospace.

Textbooks

1. J. D. Anderson, Jr., *Computational Fluid Dynamics: The Basics with Applications*, 3rd ed., Butterworth-Heinemann, 2018.
2. M. J. Quinn, *Parallel Programming in C with MPI and OpenMP*, Addison-Wesley.
3. J. Sanders and E. Kandrot, *CUDA by Example: An Introduction to General-Purpose GPU Programming*, Addison-Wesley.

Reference Books

1. H. K. Versteeg and W. Malalasekera, *An Introduction to Computational Fluid Dynamics: The Finite Volume Method*, 2nd ed., Pearson, 2007.
2. J. Tu, G. H. Yeoh, and C. Liu, *Computational Fluid Dynamics: A Practical Approach*, 3rd ed., Butterworth-Heinemann, 2018.

<table>
<tr><th colspan="2">Course Code</th><th colspan="3">Course Title</th><th>Category</th></tr>
<tr><td colspan="2">21MTAD204R</td><td colspan="3">Engineering Economics & Financial Decision-Making</td><td></td></tr>
<tr><td colspan="3">Contact Hours per Week</td><td rowspan="2">CA</td><td rowspan="2">FE</td><td rowspan="2">Credits</td></tr>
<tr><td>L</td><td>T</td><td>D/P</td></tr>
<tr><td>2</td><td>0</td><td>0</td><td>50</td><td>50</td><td>2</td></tr>
<tr><td colspan="6">Prerequisite: Basic Mathematics and Statistics.</td></tr>
<tr><td colspan="6">Course Objective:
The primary purpose of this course is to:
1. Account for the Time Value of Money: Develop the ability to incorporate present worth, annual worth, future worth, and capitalised cost in economic analyses.
2. Make Informed Economic Decisions: Apply concepts of investment analysis, including various costing methods, to guide managerial and engineering decisions.
3. Calculate Rates of Return: Gain proficiency in determining different rates of return on investments and interpreting their significance.
4. Use Economic Analysis Business from a Financial Perspective: Reasoning in Business: Adopt systematic approaches to solving business problems, integrating economic theories and financial data.
5. Understand and evaluate the financial health and strategic decisions of organisations through key financial metrics.</td></tr>
<tr><td colspan="6">Course Outcome:
By the end of the course, students will be able to:
1. CO1: Apply finance and accounting terminologies accurately in economic evaluations.
2. CO2: Prepare and appraise financial statements, interpreting their performance implications.
3. CO3: Conduct financial analyses and propose appropriate financing options based on organisational needs.
4. CO4: Use different capital budgeting methods (e.g., NPV, IRR) to foster effective financial growth and resource allocation.
5. CO5: Estimate the required return on projects with varying risks, determine cash flows, compute discount rates, and recommend accept/reject investment decisions.</td></tr>
</table>

Course Content

Unit No. 1 Introduction to Economics (9 Hours)

Economics, managerial Economics and Engineering Economics, Managerial decisions and analysis (Case study), Objectives of the firm and its attainment strategies, Elements of cost in decision making – Marginal cost Marginal revenue, Opportunity cost trade off situation, replacement decisions, recurring cost, Break Even Analysis – (Problems), Trade cycle – phases and business strategies.

Unit No. 2 Analysis of Economic Theory (9 Hours)

Demand- demand schedule and demand curve. Demand Forecasting – methods and problems, Supply – supply schedule and supply curve, Elasticity of demand – calculation, types and strategies. Market Structure, Government budget – structure and components, Pricing – methods and strategies, Taxation – tax effect analysis, GST.

Unit No. 3 Introduction to Financial Management (9 Hours)

Concept of Finance, Corporate Finance, Finance Functions and other functions. Financial statements – Balance sheet and Profit & Loss. Financial Management – Meaning and Objectives, Scope and Functions of Financial Management, Financial Planning and Forecasting.

Unit No. 4 Working Capital Management (9 Hours)

Working Capital Management – Nature of Working Capital Management, need for working capital – operating cycle, estimation of working capital requirement –Management of Cash and Receivables, Cash Budget.

Unit No. 5 Ratio Analysis and Capital Budgeting (9 Hours)

Liquidity ratios, Profitability ratios, Turnover ratios, Solvency ratios, Technics of Capital Budgeting – Pay-Back Period, Average Rate of Return, Net Present Value, Profitability Index and Internal Rate of Return.

Textbook:

1. I. M. Pandey, *Financial Management*. New Delhi, India: Vikas Publishing House.

Reference Books:

1. N. M. Vechalekar, *Financial Management*. Pune, India: Nirali Publication.
2. P. Chandra, *Financial Management*, 9th ed. New Delhi, India: McGraw Hill Education.
3. R. M. Shrivastava, *Financial Management & Policy*. Mumbai, India: Himalaya Publishing House.
4. M. Y. Khan and P. K. Jain, *Financial Management*, 7th ed. New Delhi, India: McGraw Hill Education.

<table>
<tr><th>Course Code</th><th colspan="4">Course Title</th><th>Category</th></tr>
<tr><td>25MTAD205R</td><td colspan="4">Advanced Aerodynamic Simulations – Lab</td><td>CFDL</td></tr>
<tr><td colspan="3">Contact Hours per Week</td><td rowspan="2">CA</td><td rowspan="2">FE</td><td rowspan="2">Credits</td></tr>
<tr><td>L</td><td>T</td><td>D/P</td></tr>
<tr><td>0</td><td>0</td><td>4</td><td>50</td><td>50</td><td>2</td></tr>
<tr><td colspan="6">Prerequisite:
Lab 1 Knowledge; Understanding of turbulence, compressible flows, and advanced aerodynamic phenomena; Basic Verification & Validation Concepts.</td></tr>
<tr><td colspan="6">Course Objectives:
The primary purpose of this course is to:
1. Advance CFD Skills by introducing turbulence modeling, compressible flows, and 3D wing simulations.
2. Enable Complex Analyses such as vortex shedding, shock waves, and parametric studies in aerodynamic contexts.
3. Promote Independent Problem-Solving through a capstone mini-project, integrating theoretical, numerical, and validation steps.</td></tr>
<tr><td colspan="6">Course Outcomes:
After learning this course, students shall be able to:
1. CO1: Implement turbulence models (k-ε, k-ω, etc.) for external and internal flows at higher Reynolds numbers.
2. CO2: Simulate compressible flow phenomena (transonic, supersonic) and interpret shock/expansion patterns.
3. CO3: Analyze advanced aerodynamic scenarios (3D wings, rotating systems, or heat transfer) and discuss key performance metrics.
4. CO4: Validate simulation data against experimental or published results, applying systematic verification methods.
5. CO5: Design and execute an independent mini-project, demonstrating comprehensive CFD competency from setup to final analysis.</td></tr>
</table>

LIST OF EXPERIMENTS

Any eight experiments should be selected from the list provided.

1. **2D Turbulent Flow Over a Cylinder: Vortex Shedding & Strouhal Number**
   Reynolds number is increased to promote turbulent vortex shedding. Students run a transient simulation using appropriate turbulence models, track lift/drag oscillations, and extract the Strouhal number, illustrating unsteady aerodynamic behavior.
2. **2D Airfoil with Turbulence: Stall Onset & Performance**
   An airfoil is analyzed under moderate or high Reynolds numbers using turbulence models like k-ω or SST. Students vary angle of attack, identify stall onset, and compare lift/drag curves with available experimental data or known airfoil polars.
3. **Parametric Angle-of-Attack Study for Airfoil Lift-Drag Analysis**

Through parametric design points, multiple angles of attack are automated in ANSYS. Students generate lift/drag polars and observe aerodynamic trends, reinforcing how to efficiently run and interpret multiple simulations in a single project.

4. **Transonic Flow Over an Airfoil: Shock Formation & Drag Divergence**
   Mach numbers are set near transonic conditions (around M=0.75–0.8). Students capture the formation of a normal or oblique shock on the airfoil surface and observe the drag rise phenomena, highlighting compressible flow solver requirements.
5. **Supersonic Flow Over a Wedge: Oblique Shocks & Wave Interactions**
   A 2D wedge geometry is used at supersonic speed (M>1.5) to showcase shock-wave formation and reflections. This lab clarifies high-speed boundary conditions and discusses shock angles, comparing them to theoretical shock equations.
6. **Convergent-Divergent Nozzle Flow: Mach Distribution & Shock Patterns**
   Students use a density-based solver for a convergent-divergent nozzle at supersonic outflow. They analyze internal shock structures under over- and under-expanded conditions, correlating numerical results with 1D isentropic relations.
7. **3D Wing Analysis: Induced Drag & Wingtip Vortices**
   A rectangular or tapered wing is simulated in a 3D domain. Students examine lift distribution along the span, induced drag contributions, and the flow structure around wingtip vortices, reinforcing 3D meshing and boundary-layer resolution strategies.
8. **Rotating Machinery Simulation: Basic Turbomachinery Flow**
   A rotating reference frame is set up for a simple rotor or radial fan. Students explore rotating domain concepts, torque calculation, and flow patterns in turbomachinery applications, extending CFD beyond fixed aerodynamic objects.
9. **Forced Convection Heat Transfer: CFD Analysis of Cooling Flow**
   A cooling passage or heated flat plate scenario introduces coupling between fluid flow and heat transfer. Students evaluate temperature fields, discuss Nusselt number calculations, and reinforce boundary condition choices for conjugate heat transfer problems.
10. **Capstone Mini-Project: Advanced/Custom Flow Simulation**
    Students select a complex geometry or flow scenario (e.g., UAV wing-body combination, nozzle with swirl, multi-element airfoil). The project demands an end-to-end CFD study—geometry, mesh, solver setup, validation—and a comprehensive report or presentation.

Text Book

1. Tu, J., Yeoh, G. H., & Liu, C., *Computational Fluid Dynamics: A Practical Approach*, 3rd ed., Butterworth-Heinemann, 2018.

Reference Books / Notes

1. Versteeg, H. K. & Malalasekera, W., *An Introduction to Computational Fluid Dynamics: The Finite Volume Method*, 2nd ed., Pearson, 2007.
2. Ansys Software Tutorial: Introduction to Ansys Fluent #1 – First CFD Simulation, Mitchell Boots, University of Newcastle, edited by the Ansys Academic Development Team, *PDF Link*.

Additional Video/Online Resource

1. Cornell University FLUENT Learning Modules
   (A collection of step-by-step tutorials and video guides illustrating how to set up and solve fluid flow problems in ANSYS Fluent.)

<table>
<tr><th colspan="3">Course Code</th><th colspan="3">Course Title</th><th>Category</th></tr>
<tr><td colspan="3">25MTAD206R</td><td colspan="3">Mini Project</td><td>Program Core</td></tr>
<tr><td colspan="3">Contact Hours per Week</td><td rowspan="2">CA</td><td rowspan="2">FE</td><td rowspan="2" colspan="2">Credits</td></tr>
<tr><td>L</td><td>T</td><td>D/P</td></tr>
<tr><td>0</td><td>0</td><td>4</td><td>50</td><td>50</td><td colspan="2">2</td></tr>
<tr><td colspan="7">Prerequisite: A fundamental understanding of the core concepts in the relevant subject area, with the ability to read and interpret technical papers and research articles.</td></tr>
<tr><td colspan="7">Course Objectives
The primary purpose of this course is to:
1. Identify and Compare Technical & Practical Issues: Enable students to explore advanced or emerging topics in their area of specialisation.
2. Develop Scholarly Skills: Encourage creating an annotated bibliography from research papers, demonstrating thorough literature investigation.
3. Refine Technical Writing & Critical Thinking: Train students to prepare well-structured reports and technical documents.
4. Enhance Presentation Skills: Improve competence in describing, interpreting, and analysing technical findings, culminating in effective oral presentations.</td></tr>
<tr><td colspan="7">Course Outcomes
By the end of the course, students will be able to:
1. Establish Motivation for a chosen topic and develop a structured thought process for technical communication.
2. Organize a Detailed Literature Survey and synthesise findings in a coherent document referencing significant technical publications.
3. Analyze and Comprehend proof-of-concept data or theoretical underpinnings related to the selected topic.
4. Deliver Effective Presentations that showcase clarity of thought, improved soft skills, and command of the subject.
5. Utilize Modern Tools (e.g., LaTeX) for preparing high-quality technical reports, thereby embracing recent technology in document creation.</td></tr>
</table>

Course Content

During the Mini-Project, students shall:

1. Select a Research Topic: Identify an advanced or emerging area relevant to their specialization.
2. Conduct a Literature Review: Summarize and critique research papers, focusing on existing methodologies, findings, and gaps in knowledge.
3. Perform Data Collection & Analysis: Gather information from published works, compare methodologies, and draw inferences.
4. Prepare a Seminar Report: Document objectives, literature findings, methods (if any data were collected), and conclusions in a structured format.
5. Deliver a Presentation: Present the summarised work, highlighting the key concepts, contributions, and future scope.

Important Note on Paper Presentation (25% Weightage)

25% of the overall evaluation (Continuous Assessment) will be assigned to presenting a paper based on the seminar topic at a national or international conference (publication in conference proceedings is encouraged; online publication is optional).

ELECTIVE–I

(Specialization in Aerodynamics)

Course Code	Course Title				Category
25MTAD211R	**Aerodynamic Design Optimization and Inverse Methods**				**DCC**
Contact Hours per Week			**CA**	**FE**	**Credits**
L	**T**	**D/P**			
3	**0**	**0**	**50**	**50**	**3**

Prerequisite: Aerodynamics; CFD, Numerical methods; Calculus; Linear algebra; Programming

Course Objectives:
The main purpose of this course is to:
1. **Introduce** students to both gradient-based and heuristic optimization techniques as applied to aerodynamic design.
2. **Develop** skills in shape parameterization and adjoint-based methods to enhance aerodynamic performance.
3. **Integrate** CFD with design optimization tools to solve inverse problems in aerospace engineering.
4. **Provide** practical exposure through case studies and computational projects that mimic real-world design challenges.
5. **Prepare** graduates for industry roles in aerodynamic design optimization and CFD applications.

Course Outcomes:
After learning this course, students shall be able to:
1. **CO1: Describe** the principles of gradient-based and heuristic optimization techniques used in aerodynamic design.
2. **CO2: Implement** shape parameterization methods and adjoint-based approaches in a CFD environment.
3. **CO3: Solve** inverse problems in aerodynamic design by determining optimal design parameters from desired performance criteria.
4. **CO4: Analyze** and compare the performance improvements achieved via different optimization methods.
5. **CO5: Develop** a complete design optimization project report integrating CFD results with inverse problem solutions, demonstrating readiness for industry applications.

COURSE CONTENT

Unit 1: Introduction to Aerodynamic Optimization (9 Hours)

Overview of optimization in aerospace design; Fundamentals of gradient-based optimization methods; Introduction to heuristic (evolutionary) optimization techniques; Basic formulation of inverse problems in aerodynamics.

Unit 2: Shape Parameterization Techniques (9 Hours)

Methods for representing aerodynamic shapes (e.g., Hicks-Henne functions, free-form deformation); Sensitivity analysis of shape changes; Implementation of shape parameterization in CFD solvers.

Unit 3: Adjoint-Based Optimization Methods (9 Hours)

Fundamentals of the adjoint method in CFD; Formulation of adjoint equations and sensitivity derivatives; Implementation in aerodynamic design tasks; Case studies highlighting efficiency gains in optimization.

Unit 4: Heuristic and Evolutionary Optimization (9 Hours)

Overview of genetic algorithms and other heuristic optimisation methods; Multi-objective optimization techniques in aerodynamic design; Comparison with gradient-based methods; Integration with CFD for robust design exploration.

Unit 5: Applications and Case Studies in Inverse Aerodynamic Design (9 Hours)

End-to-end case studies: From setting design objectives to obtaining optimal aerodynamic performance; CFD-based validation of optimized designs; Discussion of practical challenges, trade-offs, and uncertainty quantification; Presentation of design projects with a focus on inverse problem solutions.

Textbook

1. R. T. Haftka and Z. Gürdal, *Introduction to Design Optimization: Theory and Applications*, 2nd ed., Wiley, 2002.

Reference Books

1. K. Deb, *Multi-Objective Optimization Using Evolutionary Algorithms*, Wiley, 2001.
2. S. S. Rao, *Engineering Optimization: Theory and Practice*, 4th ed., Wiley, 2009.
3. AIAA Journal papers on adjoint-based optimization and inverse aerodynamic design.

Course Code	Course Title				Category
25MTAD212R	**Unsteady Aerodynamics & Aeroelasticity**				**ToT**
Contact Hours per Week			**CA**	**FE**	**Credits**
L	**T**	**D/P**			
3	**0**	**0**	**50**	**50**	**3**

Prerequisite: Aerodynamics; Structural Mechanics; Numerical Methods/CFD.

Course Objectives:

The main purpose of this course is to:

1. **Introduce** students to time-varying aerodynamic phenomena and the fundamental principles of unsteady flows.
2. **Examine** the causes and consequences of aeroelastic instabilities such as flutter and dynamic stall.
3. **Develop** proficiency in numerical methods for predicting unsteady aerodynamic responses and fluid–structure interactions (FSI).
4. **Integrate** theoretical concepts with practical CFD approaches to simulate and mitigate unsteady aerodynamic issues.
5. **Prepare** students for industry challenges by equipping them with tools for designing control strategies and optimizing aeroelastic performance.

Course Outcomes:

After learning this course, students shall be able to:

1. **CO1: Describe** the key characteristics of unsteady aerodynamic phenomena and explain the underlying physical mechanisms.
2. **CO2: Analyze** flutter and aeroelastic instabilities using classical theories and numerical simulation techniques.
3. **CO3: Implement** coupled CFD and structural analysis methods to study fluid–structure interactions.
4. **CO4: Evaluate** the effectiveness of various control strategies (active and passive) for mitigating unsteady aerodynamic issues.
5. **CO5: Develop** a complete simulation case study that integrates unsteady aerodynamic analysis with aeroelastic design optimization.

COURSE CONTENT

Unit 1: Fundamentals of Unsteady Aerodynamics

Introduction to time-varying aerodynamic phenomena; Analysis of unsteady forces, dynamic pressure fluctuations, and transient responses; Strouhal number; Fourier analysis and frequency-domain representation of unsteady flows; Application of unsteady aerodynamic theories to simple configurations.

Unit 2: Flutter and Aeroelastic Instabilities

Introduction to aeroelasticity and the fundamentals of flutter; Classical flutter theory (e.g., Theodorsen's theory, strip theory); Dynamic stability analysis and the onset of dynamic stall; Case studies on flutter phenomena in wings and airfoils.

Unit 3: Fluid–Structure Interaction (FSI)

Principles of fluid–structure interaction and coupling between CFD and structural solvers; Numerical methods for FSI (coupled CFD/FE approaches and reduced-order models); Examples of FSI in aeroelastic applications; Discussion of experimental validation of FSI simulations.

Unit 4: Numerical Methods for Unsteady CFD

Time-integration schemes for transient CFD simulations: explicit and implicit methods; Stability and convergence criteria for unsteady flow simulations; Adaptive time-stepping and error control strategies; Case studies of unsteady aerodynamic simulations using commercial CFD codes.

Unit 5: Mitigation and Control of Unsteady Aerodynamic Phenomena

Active and passive control strategies for reducing flutter and unsteady loads; Design modifications and damping techniques to mitigate aeroelastic instabilities; Integration of CFD-based optimization with flow control methods; Industrial case studies and recent research trends in unsteady flow control.

Textbook

1. L. Bisplinghoff, H. Ashley, and R. L. Halfman, *Aeroelasticity*, 2nd ed., Dover Publications, 2003.

Reference Book

1. M. P. Païdoussis, *Fluid-Structure Interactions: Slender Structures and Axial Flow*, 3rd ed., Elsevier, 2011.
2. J. Tu, G. H. Yeoh, and C. Liu, *Computational Fluid Dynamics: The Basics with Applications*, 3rd ed., Butterworth-Heinemann, 2018.
3. Selected AIAA/ASME journal articles on unsteady aerodynamics and advanced FSI methods.

SEMESTER –III

Course Code	Course Title				Category
25MTAD301R	**Advanced Research Methodologies and Scientific Communication**				**DCC**
Contact Hours per Week			**CA**	**FE**	**Credits**
L	**T**	**D/P**			
3	**0**	**0**	**50**	**50**	**3**

Prerequisite:

1. Basic knowledge of research methods and academic writing.
2. Familiarity with common computer applications (e.g., Microsoft Office).
3. An introductory understanding of data management and analysis concepts.

Course Objectives:

The main purpose of this course is to:

1. Introduce the fundamentals of scholarly research by identifying problems, defining objectives, and conducting literature reviews using both traditional and AI-enhanced methods.
2. Develop practical skills in managing and analyzing research data using tools like Microsoft Excel and Power BI.
3. Integrate AI tools to accelerate literature reviews, data cleaning, and preliminary report drafting.
4. Guide students in drafting professional theses and manuscripts with Microsoft Word and reference management software.
5. Enhance scientific communication and presentation skills to effectively convey research findings in academic and professional forums.

Course Outcomes:

After learning this course, students shall be able to:

1. CO1: Identify and articulate clear research objectives and gaps by conducting comprehensive literature reviews and leveraging AI tools like Semantic Scholar and ResearchRabbit.
2. CO2: Analyze and visualize research data effectively using tools such as Excel and Power BI, enabling data-driven decision making.
3. CO3: Apply AI-driven methodologies to streamline literature searches, data cleaning, and report drafting, thereby enhancing overall research productivity.
4. CO4: Produce high-quality research documents and manuscripts by mastering advanced documentation skills and peer-review processes using Microsoft Word, Zotero, or Mendeley.
5. CO5: Communicate research findings persuasively through well-designed presentations, academic posters, and digital media, utilizing AI design tools like Beautiful.ai and Canva.

COURSE CONTENT

Unit 1: Research Foundations – Defining Objectives, Literature Review, and Gap Analysis (9 Hours)

- Literature Search & Review Lab:
  - Conduct hands-on sessions using academic databases (e.g., IEEE Xplore, Google Scholar) to gather and synthesize key research findings.
  - Introduce AI tools such as Semantic Scholar, Connected Papers, and ResearchRabbit to streamline literature discovery and identify influential papers.
- Gap Analysis Exercise:
  - Participate in group discussions to identify areas where current research is lacking and propose potential research directions.
- Drafting a Research Proposal Outline:
  - Begin outlining a research proposal that captures your research rationale, objectives, and a preliminary methodology.

Unit 2: Data Management and Analytical Tools for Research (9 Hours)

- Excel Data Workshop:
  - Practice data entry, formatting, and basic formula applications using real-world research datasets.
  - Exercises include data validation, conditional formatting, and use of lookup functions.
- Data Analysis & Visualization:
  - Create pivot tables and construct charts to reveal trends and insights within datasets.
- Power BI Dashboard Lab:
  - Connect to diverse data sources and build interactive dashboards that effectively communicate research findings.
- Case Study Exercise:
  - Analyze a sample dataset from a research study to extract key insights and trends, presenting findings through visualizations.

Unit 3: Leveraging AI Tools for Enhanced Research and Writing (9 Hours)

- AI Tool Demonstrations:
  - Interactive sessions showcasing popular AI tools such as ChatGPT, Grammarly, Jasper, and Elicit.
  - Introduce additional tools like SciNote (for research data management) and Ref-N-Write (for academic writing assistance).
- Enhanced Literature Review:
  - Use AI tools to streamline literature searches, extract key insights, and generate summaries.
- Data Cleaning & Preliminary Analysis:
  - Hands-on sessions where AI automates data cleaning processes and assists with initial data analysis.
- Interactive Report Writing:
  - Draft and edit research report sections with AI assistance, focusing on improving clarity, grammar, and coherence.
- Case Study Analysis:
  - Work in groups to apply AI-driven approaches to solve specific research challenges, followed by group discussion on outcomes and tool effectiveness.

Unit 4: Scientific Documentation, Thesis Drafting, and Journal Manuscript Preparation (9 Hours)

- Microsoft Word Immersion:
  - Live demonstrations and guided exercises on the interface, formatting tools, and style management.
- Thesis Drafting Lab:
  - Create key sections of a thesis document, including the title page, abstract, and structured chapter headings using predefined templates.
- Document Formatting & Style Workshops:
  - Apply styles, headings, and automated tables of contents to ensure consistency throughout the document.
- Reference Management:
  - Utilize tools like Zotero or Mendeley for efficient citation management and seamless integration into your document.
- Journal Manuscript Structuring:
  - Learn to organize a journal article into clear sections—abstract, introduction, methodology, results, discussion, and conclusion.
- Drafting and Peer Review:
  - Participate in simulated peer-review sessions using track changes and comments to refine and polish manuscript drafts.
- Revision & Finalization Sessions:
  - Iteratively refine the document based on peer feedback to achieve a submission-ready manuscript.

Unit 5: Scientific Communication and Presentation Skills (9 Hours)

- Presentation Design Workshop:
  - Learn best practices for designing visually engaging slides using tools like PowerPoint and Canva.
  - Explore AI-driven design assistants such as Beautiful.ai or DesignScape for creating professional slide decks.
- Poster Development Lab:
  - Create academic posters that clearly present research objectives, methodology, results, and conclusions.
  - Utilize AI tools like PosterMyWall for layout and design enhancement.
- Mock Presentation Sessions:
  - Deliver short presentations to peers, with structured feedback sessions on clarity, content, and delivery.
- Interactive Communication Exercises:
  - Engage in role-playing scenarios to practice answering questions and defending research findings in academic settings.
- Digital Communication Tools:
  - Explore online platforms for webinars, virtual conferences, and digital content sharing (e.g., Zoom, Microsoft Teams, and Prezi).

Textbook

1. W. C. Booth, G. G. Colomb, and J. M. Williams, *The Craft of Research*, 3rd ed., Chicago, IL, USA: University of Chicago Press, 2008.

Reference Book

1. J. Schimel, *Writing Science: How to Write Papers That Get Cited and Proposals That Get Funded*, New York, NY, USA: Oxford University Press, 2012.

<table>
<tr><th>Course Code</th><th colspan="4">Course Title</th><th>Category</th></tr>
<tr><td>25MTAD301R</td><td colspan="4">TECHNICAL SEMINAR -II</td><td>Program Core</td></tr>
<tr><th colspan="3">Contact Hours per Week</th><th rowspan="2">CA</th><th rowspan="2">FE</th><th rowspan="2">Credits</th></tr>
<tr><th>L</th><th>T</th><th>D/P</th></tr>
<tr><td>0</td><td>0</td><td>4</td><td>50</td><td>50</td><td>2</td></tr>
<tr><td colspan="6">Prerequisite: Fundamental Research Exposure; Analytical and Presentation Skills.</td></tr>
<tr><td colspan="6">Course Objectives
The primary purpose of this course is to:
1. Identify and Compare Technical & Practical Issues: Enable students to delve deeper into advanced or emerging topics within their specialisation, building upon prior seminar experience.
2. Develop Scholarly Skills: Enhance competency in creating annotated bibliographies and critically reviewing research papers with a strong methodological focus.
3. Refine Technical Writing & Critical Thinking: Strengthen the ability to organise and compose technical reports demonstrating clarity, precision, and logical reasoning.
4. Enhance Presentation Competence: Foster the skills to describe, interpret, and analyse technical issues, culminating in clear oral communication.</td></tr>
<tr><td colspan="6">Course Outcomes (CO)
By the end of the course, students will be able to:
1. Establish motivation for a specialised topic and develop a coherent structure for technical presentations.
2. Organize an in-depth literature survey and compose a detailed document referencing core technical publications.
3. Analyse and synthesise proof-of-concept data or theoretical constructs relevant to advanced research problems.
4. Deliver impactful presentations, refining both communication techniques and subject-matter expertise.
5. Adopt contemporary tools (e.g., LaTeX) for producing high-quality, publication-ready technical reports.</td></tr>
</table>

Course Content

During Technical Seminar - II, students will:

1. Explore Advanced Research Themes: Identify current or emerging issues beyond the scope of prior seminars, ensuring progression in technical understanding.
2. Conduct Comprehensive Literature Reviews: Examine multiple research publications, focusing on experimental design, methodology, and data interpretation for comparative analysis.
3. Perform Critical Analysis: Evaluate the strengths, weaknesses, and potential gaps in existing studies, proposing potential areas for further inquiry.
4. Compile a Detailed Seminar Report: Document the research scope, findings, and synthesized perspectives with clarity and professional rigor.

5. Present Findings: Showcase the study’s conclusions in a formal seminar setting, defending the rationale and significance of the chosen topic.

Important Note on Paper Presentation (50% of CA):

50% of the continuous assessment will be based on presenting a paper at an international conference (with online publication). This step ensures students gain real-world academic exposure and experience disseminating their research to a broader audience.

Course Code	Course Title				Category
25MTAD302R	**Dissertation Phase -I**				Program Core
Contact Hours per Week			CA	FE	Credits
L	T	D/P			
0	0	16	50	50	08
Prerequisite: Fundamental Knowledge of Domain; Research Methodology Skills.					

Course Objectives

The primary purpose of this course is to:

1. **Apply Fundamental Concepts:** Investigate related literature from fundamental subjects to identify a clear research gap.
2. **Formulate the Research Problem:** Define objectives and scope for the project, ensuring clarity in the problem statement.
3. **Analyze Available Resources:** Evaluate tools, methodologies, and data sources needed for successful project execution.
4. **Enhance Presentation & Communication Skills:** Improve clarity in reporting progress, findings, and project outcomes in both written and oral formats.

Course Outcome:

By the end of the course, students will be able to:

1. CO1: Identify a pertinent research gap through a detailed literature review, referencing at least five scholarly articles or industry sources.
2. CO2: Formulate a clear problem statement and research objectives, providing a structured plan (e.g., Gantt chart) to address the identified gaps.
3. CO3: Select and justify appropriate methodologies, tools, and resources, demonstrating alignment with project objectives and constraints (e.g., budget, time, scope).
4. CO4: Develop a comprehensive project proposal or progress report, incorporating standardized formatting and documentation guidelines, with at least 80% adherence to the specified criteria.
5. CO5: Present the proposed project approach and findings (e.g., methodology, preliminary data, expected outcomes) to a review committee, achieving a minimum set score or rubric standard for clarity and depth of analysis.

Course Content

During Project Phase - I, students shall:

1. **Finalize a Theme:** Select a topic aligned with their area of specialization for the dissertation work.
2. **Conduct Extensive Literature Review:** Define the research gap, objectives, and scope.
3. **Plan Methodology:** Propose a structured approach that may include laboratory experiments, model development, case studies, or field data collection.
4. **Compile Progress Report:** Document the chosen research approach, initial findings, and methodology in a cohesive format adhering to institutional guidelines.
5. **Present Work to the Review Committee:** Offer an oral presentation detailing the research plan, literature survey outcomes, and proposed methods.

ELECTIVE–II

(Specialisation in Aerodynamics)

Course Code	Course Title				Category
25MTAD321R	**Advanced Boundary Layer Theory**				**DCC**
Contact Hours per Week			**CA**	**FE**	**Credits**
L	**T**	**D/P**			
3	**0**	**0**	**50**	**50**	**3**
Prerequisite: Fluid mechanics; Numerical methods.					

Course Objectives:

The primary purpose of this course is to:

1. **Introduce** advanced concepts in laminar-to-turbulent transition, boundary layer stability, and separation control.
2. **Develop** analytical and computational skills for predicting and mitigating unsteady flow phenomena.
3. **Explore** modern computational techniques for simulating complex boundary layer behavior.
4. **Integrate** theory with practical applications to enhance aerodynamic performance in aerospace designs.

Course Outcomes:

After learning this course, students shall be able to:

1. **CO1: Explain** the fundamental mechanisms governing laminar-to-turbulent transition in boundary layers.
2. **CO2: Analyze** boundary layer stability and predict the onset of flow separation using both classical and modern theories.
3. **CO3: Evaluate** various separation control techniques and assess their effectiveness in delaying or mitigating separation.
4. **CO4: Apply** advanced computational methods to model boundary layer behavior and validate predictions with experimental data.
5. **CO5: Propose** design modifications for aerodynamic improvement based on in-depth boundary layer analysis.

COURSE CONTENT

Unit 1: Fundamentals of Boundary Layer Theory **(9 Hours)**

Overview of laminar boundary layers; Derivation of the Blasius solution; Assumptions underlying classical boundary layer theory; Importance of thin-layer approximations; Role of viscosity in near-wall flow.

Unit 2: Laminar-Turbulent Transition **(9 Hours)**

Detailed discussion on laminar-to-turbulent transition; Examination of Tollmien–Schlichting waves; Linear stability theory; Effects of surface roughness and disturbances.

Unit 3: Turbulent Boundary Layers **(9 Hours)**

Characteristics of fully turbulent boundary layers; Derivation of empirical correlations; Turbulent mixing and its influence on shear stress.

Unit 4: Separation Control and Flow Stability **(9 Hours)**

Causes and effects of boundary layer separation; Active and passive methods (suction, blowing, vortex generators); Methods to delay transition and stabilize flow.

Unit 5: Advanced Computational Boundary-Layer Modeling (9 Hours)

Modern CFD techniques for simulating boundary layers; Strategies for resolving transition and separation; Comparing CFD predictions with experimental data.

Textbook

1. H. Schlichting and K. Gersten, *Boundary-Layer Theory*, 9th ed., Springer, 2017.

Reference Books

1. S. B. Pope, *Turbulent Flows*, 1st ed., Cambridge University Press, 2000.
2. F. M. White, *Viscous Fluid Flow*, 3rd ed., McGraw-Hill, 2006.
3. H. K. Versteeg and W. Malalasekera, *An Introduction to Computational Fluid Dynamics: The Finite Volume Method*, 2nd ed., Pearson, 2007.

<table>
<tr><th>Course Code</th><th colspan="4">Course Title</th><th>Category</th></tr>
<tr><td>25MTAD322R</td><td colspan="4">Rotary Wing Aerodynamics</td><td>RWA</td></tr>
<tr><td colspan="3">Contact Hours per Week</td><td rowspan="2">CA</td><td rowspan="2">FE</td><td rowspan="2">Credits</td></tr>
<tr><td>L</td><td>T</td><td>D/P</td></tr>
<tr><td>3</td><td>0</td><td>0</td><td>50</td><td>50</td><td>3</td></tr>
<tr><td colspan="6">Prerequisite: Fluid Dynamics, Aerodynamics</td></tr>
</table>

Course Objectives:

The primary purpose of this course is to:

1. **Provide a Comprehensive Understanding:** Introduce the historical evolution, basic configurations, and control requirements of helicopters, covering the various rotor systems (main and tail) and fundamental power requirements.
2. **Develop Theoretical and Analytical Skills:** Enable students to apply momentum theory, blade element theory, and their combined approaches to predict and analyze helicopter performance in hovering, vertical, and forward flight.
3. **Analyze Flight Regimes:** Equip students with the tools to assess the aerodynamic performance of rotorcraft across different flight states, including hovering, vertical climb/descent, and forward flight.
4. **Examine Trim and Stability:** Train students to analyze the equilibrium and trim characteristics of helicopters, including force/moment balances and natural modes of motion.
5. **Bridge Theory with Industry Applications:** Prepare students for aerospace industry roles by integrating theoretical analysis with practical design considerations and performance optimization techniques.

Course Outcomes:

After learning this course, students shall be able to:

1. **CO1: Summarize** the historical development and configurations of helicopters, including the functions of main and tail rotors.
2. **CO2: Apply** momentum and blade element theories to calculate key performance parameters (thrust, power, torque coefficients) in hovering flight.
3. **CO3: Evaluate** vertical flight performance by analyzing flow states, autorotation, power loading, and disk loading for rotorcraft.
4. **CO4: Analyze** forward flight aerodynamics using variable inflow models and blade element theory to predict rotor blade flapping, hub loads, and power variation with speed.
5. **CO5: Determine** trim and stability characteristics through force and moment balances, and assess the natural modes of motion to ensure safe helicopter operation.

COURSE CONTENT

Unit-1 Introduction **(9 Hours)**

Historical Development of Helicopters, Helicopter Configuration, Control Requirements, Types of Rotor Systems, Basic Power Requirements, Rotorcraft Definitions, Types of Rotorcraft Rotorcraft Configurations, Main Rotor Configuration, Tail Rotor Configuration

Unit-2 Hovering flight theory (9 Hours)

Momentum Theory, Blade Element Theory, Combined Blade Element and Momentum theories for non-uniform inflow calculation, Ideal Rotor Vs Optimum Rotor, Induced Velocity, Induced Inflow Ratio, Thrust Coefficient (CT), Power Coefficient (CP), Torque Coefficient

Unit-3 Vertical flight theory (9 Hours)

Various flow states of the Rotor, Autorotation in Vertical Descent, Ground Flight, vertical climb, Power Loading, Disk Loading, Power Requirement

Unit-4 Forward flight theory (9 Hours)

Momentum Theory, Variable Infow Models, Blade Element Theory, Rotor Reference Planes, Hub Loads, Power variation with forward speed, Rotor Blade flapping Motion: Simple Model.

Unit-5 Helicopter trim and stability (9 Hours)

Equilibrium condition of helicopter, Trim analysis, General trim pattern, longitudinal partial trim, lateral/directional partial trim, Balances of forces and moments, Basics of helicopter stability, Stability analysis, Natural modes of motion.

Textbooks

1. J. Gordon Leishman, “Principles of Helicopter Aerodynamics”, Cambridge Aerospace Series, Latest Available Edition, ISBN 3781107013353.
2. John M. Seddon, Simon Newman; John Wiley, “Basic Helicopter Aerodynamics", Latest Available Edition, ISBN 97811997272-3.
3. Helicopter Aerodynamics, Structures and Systems by Aviation Maintenance Technician Certification Series, Latest Available Edition.

Reference Books

1. G. D. Padfield, “Helicopter Flight Dynamics: Including a treatment of tiltrotor aircraft”, 3rd Edition, John Wiley and Sons, The Atrium, Southern Gate, Chichester, West Sussex, ISBN 978111940105-6.

SEMESTER –IV

<table>
<tr><th>Course Code</th><th colspan="3">Course Title</th><th colspan="2">Category</th></tr>
<tr><td>25MTAD401R</td><td colspan="3">Dissertation Phase-II</td><td colspan="2">Program Core</td></tr>
<tr><td colspan="3">Contact Hours per Week</td><td rowspan="2">CA</td><td rowspan="2">FE</td><td rowspan="2">Credits</td></tr>
<tr><td>L</td><td>T</td><td>D/P</td></tr>
<tr><td>0</td><td>0</td><td>32</td><td>100</td><td>200</td><td>16</td></tr>
<tr><td colspan="6">Prerequisite: Successful Completion of Dissertation Phase I</td></tr>
</table>

Course Objectives

The primary purpose of this course is to:

1. Refine & Execute Methodology: Implement the full plan, making adjustments based on Phase-I feedback or newly encountered challenges.
2. Validate & Correlate Findings: Compare experimental outcomes with computational results, or vice versa, ensuring accuracy and consistency.
3. Present Final Deliverables: Compile comprehensive results, analyses, and conclusions, culminating in a final dissertation and viva-voce.

Course Outcomes (CO)

By the end of Project Phase – II, students will be able to:

1. CO1: Implement the research methodology thoroughly, incorporating necessary refinements from Phase-I feedback.
2. CO2: Analyze and Validate final data/results, using experimental or computational means (or both), demonstrating correlation and coherence.
3. CO3: Synthesize insights and draw evidence-based conclusions, highlighting advancements or innovative findings from the research.
4. CO4: Document and Present the comprehensive dissertation, adhering to technical writing standards and institutional guidelines.
5. CO5: Publish/Disseminate findings via a journal submission or international conference presentation, aligning with professional research standards.

Course Content:

1. Methodology Refinement: Address gaps or methodological issues identified during Phase-I, updating experimental setups or computational tools.
2. Comprehensive Data Collection: Execute final experiments or simulations, ensuring sufficient replication or validation.
3. Correlation & Validation:
    a. Experimental Approach: Validate findings via simulations, mathematical models, or correlation with existing literature data.
    b. Computational Approach: Confirm accuracy using experimental benchmarks or known theoretical results.
4. Analysis & Discussion:
    a. Process raw data and derive key metrics.
    b. Compare outcomes with objectives, highlighting successes or discrepancies.
5. Final Report Writing:
    a. Present exhaustive details on methodology, results, validation, and conclusion.

  b. Follow formatting guidelines (figures, tables, equations, references).
6. Viva-Voce & Dissemination:
  a. Defend the dissertation in front of an external committee.

These two phases collectively ensure that students' progress from problem identification and planning to full-fledged research execution and scholarly dissemination.

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