MTech Aerospace Propulsion Technology
Second Semester Syllabus Academic Year 2026-2027

COMPUTATIONAL FLUID DYNAMICS			
Course Code	1MAS201	Scheme	2026
Type of Course	PCC	Semester	II
Teaching Hours/Week (L:T:P)	3 : 1 : 0	CIE Marks	50
Total Hours of Pedagogy L /T/P/SL&TW:	120 (42:28:0:50)	SEE Marks	50
Credits	4	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	3Hrs

Course Objectives

At the end of the course, the student will be able to:
CO1: Provide a strong foundation in numerical methods for fluid flow and heat transfer.
CO2: Formulate and discretize governing equations for laminar and turbulent flows.
CO3: Implement and analyse finite-difference, finite-volume and finite-element schemes.
CO4: Understand numerical stability, convergence, and verification/validation methods.
CO5: Use/extend a CFD code for practical engineering problems.

Module-1

Introduction and Governing Equations

Conservation laws (mass, momentum, energy); incompressible vs compressible flows; boundary and initial conditions; integral and differential forms; non-dimensionalization and similarity parameters.

Number of Hours: **8**

Module-2

Numerical Methods: Finite Difference and Finite Volume

Grid generation, structured vs unstructured meshes; finite-difference schemes (explicit/implicit); truncation error, consistency, stability (von Neumann); finite-volume discretization for diffusion and convection; upwind, central, QUICK schemes; conservation and boundedness.

Number of Hours: **10**

Module-3

Pressure–Velocity Coupling and Solution Algorithms

Staggered vs collocated grids; SIMPLE, SIMPLER, PISO algorithms; pressure correction methods; fractional step/projection methods for incompressible flows; boundary conditions and treatments.

Number of Hours: **8**

Module-4

Advanced Topics: Turbulence Modelling and Compressible Flow

Reynolds-averaged Navier–Stokes (RANS) models (k–ε, k–ω, SST), LES basics; compressible flow discretization, shock capturing schemes, artificial viscosity; high-resolution schemes.

Number of Hours: **8**

Module-5

Verification, Validation, and Practical CFD Applications

Code verification and validation, grid convergence studies, error estimation; turbulence model selection; case studies: laminar boundary layer, channel flow, flow over a cylinder, simple aerofoil; introduction to parallelization & performance.

Number of Hours: **8**

Textbooks:

1. J. D. Anderson, "Computational Fluid Dynamics: The Basics with Applications", McGraw-Hill.
2. C. Hirsch, "Numerical Computation of Internal and External Flows" (Vols. 1 & 2), Butterworth-Heinemann.
3. T. J. Chung, "Computational Fluid Dynamics", Cambridge Univ. Press.

Reference books / Manuals:

1. M. J. Lighthill and P. W. Carpenter (ed.), "Numerical Methods in Fluid Dynamics".
2. R. J. LeVeque, "Finite Volume Methods for Hyperbolic Problems".
3. H. Versteeg and W. Malalasekera, "An Introduction to Computational Fluid Dynamics: The Finite Volume Method".

Web links and Video Lectures (e-Resources):

1. NPTEL course: https://nptel.ac.in/courses/112105045
2. CFD Online resources: https://www.cfd-online.com/
3. Youtube videos: https://www.youtube.com/watch?v=01X5ECv3qIU&list=PLbiOzt50Bx-kV3Lcn5piPyV9EvpmOybJR

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1. Flipped Classrooms with expert seminars
2. AI-augmented collaborative learning
3. Industry/ research problem-based learning
4. Research paper review and discussion of potential solutions

Assessment Structure (both CIE and SEE)

The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the CIE, a student must score at least 40% of 50 marks, i.e., 20 marks.
- To pass the SEE, a student must score at least 35% of 50 marks, i.e., 18 marks.

Notwithstanding the above, a student is considered to have passed the course, provided the combined total of CIE and SEE is at least 40 out of 100 marks.

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of **two Internal Assessment Tests (IA)** shall be conducted, carrying a total of **25 marks**.

In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks**.

It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development of students**. These activities shall be:

Sl. No.	Name of the Learning activity	Maximum Marks
1.	Case Study / Mini-project / Optimization Exercise / Research paper Review / Programming Challenge	25

Continuous Internal Evaluation (CIE)

(i)The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.

(ii)Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test

shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.
(iii) The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.
(iv) A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE
For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.
For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.
If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade 'F' (Fail).

FUELS, COMBUSTION AND EMISSIONS IN ENGINES			
Course Code	1MAS202	Scheme	2026
Type of Course	PCC	Semester	II
Teaching Hours/Week (L:T:P)	3 : 0 :0	CIE Marks	50
Total Hours of Pedagogy L /T/P/SL&TW:	90(42 : 0 : 0 : 48)	SEE Marks	50
Credits	3	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	3Hrs

Course Objectives

At the end of the course, the student will be able to:
CO1: Analyse the physical, thermal, and combustion properties of aviation fuels.
CO2: Evaluate fuel treatment methods and alternative fuels for aerospace applications.
CO3: Analyse gas turbine combustor design and combustion fundamentals.
CO4: Evaluate combustion flame characteristics and combustion performance in gas turbine engines.
CO5: Analyse flame stabilization, fuel classification, and emission control techniques in gas turbine engines.

Module-1

Fuel Properties: Fuel Properties, Relative Density, API Gravity, Molecular Mass, Distillation Range, Vapor Pressure, Flash Point, Volatility Point, Viscosity, Surface Tension, Freezing Point, Specific Heat, Latent Heat, Thermal Conductivity, Combustion Properties of Fuels, Calorific Value, Enthalpy, Spontaneous-Ignition temperature, Limits of Flammability, Smoke Point, Luminometer Number, Smoke Volatility Index, Pressure and Temperature Effects, Sub atmospheric Pressure, Low Temperature, High Temperature.

Number of Hours:08

Module-2

Fuel Treatment: Introduction, Types of Hydrocarbons, Paraffins, Olefins, Naphthenes, Aromatics, Production of Liquid Fuels, Removal of Sulfur Compounds, Contaminants, Asphaltenes, Gum, Sediment, Ash, Water, Sodium, Vanadium, Additives, Gum Prevention, Corrosion Inhibition/Lubricity Improvers, Anti-Icing, Antistatic–Static Dissipators, Metal Deactivators, Antismoke

Alternative Fuels aerospace applications: Hydrogen, Methane, Propane, Ammonia, Alcohols, Slurry fuels, Synthetic fuels, Fuels Produced by Fischer–Tropsch Synthesis of Coal/Biomass, Biofuels, Alternative fuel Properties, Combustion and Emissions Performance, Fischer–Tropsch Fuels, Biodiesel Fuels, Highly Aromatic (Broad Specification).

Number of Hours:08

Module-3

Basic Considerations: Introduction to Gas Turbine Combustor, Basic Design Features, Combustor Requirements, Combustor Types and parts, Fuel Preparation, Atomizers, liner wall-cooling Techniques, combustor stability limits, combustor exit temperature traverse quality (pattern factors), Combustors for Low Emissions.

Combustion Fundamentals: Deflagration, Detonation, Classification of Flames, Physics of combustion Chemistry, Flammability Limits, Global Reaction-Rate Theory, Weak Mixtures, Rich Mixtures, Laminar Premixed Flames, laminar and turbulent flame burning velocity, measurement techniques for flame velocity, Factors Influencing Laminar Flame Speed, Equivalence Ratio, Initial Temperature, Pressure, Laminar Diffusion Flames, Turbulent Premixed Flames, Flame Propagation in Heterogeneous Mixtures of Fuel Drops, Fuel Vapour and Air.

Number of Hours: 09

Module-4

Combustion flame characterization: Droplet and Spray Evaporation, Heat-Up Period, Evaporation Constant, Convective Effects, Effective Evaporation Constant, Spray Evaporation, Ignition Theory, Gaseous Mixtures, Heterogeneous Mixtures, Spontaneous Ignition, Flashback, Stoichiometry, Adiabatic Flame Temperature, Factors Influencing the Adiabatic Flame Temperature, Fuel/Air Ratio, Initial Air Temperature, Pressure.

Combustion Performance: Combustion Efficiency, The Combustion Process, Reaction-Controlled Systems, Burning Velocity Model, Stirred Reactor Model, Mixing-Controlled Systems, Evaporation-Controlled Systems, Reaction- and Evaporation-Controlled Systems.

Number of Hours: 08

Module-5

Flame Stabilization & Fuel Classification: Definition of Stability Performance, Measurement of Stability Performance, Bluff-Body Flame holders, Stabilization, Mechanisms of Flame Stabilization, Flame Stabilization in Combustion Chambers, Classification of Liquid Fuels, Aircraft Gas Turbine Fuels, Engine Fuel System, Aircraft Fuel Specifications, Classification of Gaseous Fuels.

Emissions: Regulations, Aircraft Engines, Stationary Gas Turbines, Mechanisms of Pollutant Formation, Unburned Hydrocarbons, Smoke, Oxides of Nitrogen, Thermal Nitric Oxide, Nitrous Oxide Mechanism, Prompt Nitric Oxide, Fuel Nitric Oxide, Influence of Pressure on Oxides of Nitrogen Formation, Influence of Fuel Atomization on Oxides of Nitrogen Formation, Pollutants Reduction in Conventional Combustors.

Number of Hours:09

Textbooks:

1. H.Lefebvre & Dilip R. Ballal, “Gas Turbine Combustion, Alternative fuels and Emissions”, CRC Press, 3rd Edition, 2010
2. Minkoff, G.J., and C.F.H. Tipper, “Chemistry of Combustion Reaction”, Butterworths, London, 1962
3. Samir Sarkar, “Fuels & Combustion”, Universities Press, 3rd edition, 2009.

Reference books / Manuals:

1. Hill, P. and Peterson, C., Mechanics and Thermodynamics of Propulsion, 2nd Ed., Pearson, 2020.
2. Mattingly, J. D., Heiser, W. H., and Pratt, D. T., Aircraft Engine Design, 3rd Ed., AIAA, 2018.
3. Runchal, A. K., et al. (Eds.), Energy for Propulsion: A Sustainable Technologies Approach, Springer, 2018.

Web links and Video Lectures (e-Resources):

1. https://www.nasa.gov/glenn/research/chemical-equilibrium-with-applications/
2. https://ocw.mit.edu/courses/2-61-internal-combustion-engines-spring-2017/pages/lecture-notes/
3. https://ocw.mit.edu/courses/2-61-internal-combustion-engines-spring-2017/
4. https://www.nptel.ac.in/courses/112103262/

Teaching-Learning Process (Innovative Delivery Methods):
The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1. Project-based learning
2. Flipped classroom with micro learning
3. Case-based learning
4. Virtual laboratories / AI-assisted exercises

Assessment Structure:
The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks**.
- To pass the **SEE**, a student must score at least **35% of 50 marks**, i.e., **18 marks**.

Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE** is at least **40 out of 100 marks**.

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of **two Internal Assessment Tests(IA)** shall be conducted, carrying a total of **25 marks**.

In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks**.

It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development of students**. These activities shall be:

Sl. No.	Name of the Learning activity	Maximum Marks
1.	Case Study / Mini-project / Optimization Exercise / Research paper Review / Programming Challenge	25

Continuous Internal Evaluation (CIE)
(i)The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.
(ii)Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.
(iii) The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.
(iv) A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE
For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.
For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.
If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade ‘F’ (Fail).

CRYOGENIC ENGINES			
Course Code	1MAS203	Scheme	2026
Type of Course	PCC	Semester	II
Teaching Hours/Week (L:T:P)	3:0:0	CIE Marks	50
Total Hours of Pedagogy L /T/P/SL&TW:	90(42 : 0 : 0 : 48)	SEE Marks	50
Credits	03	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	03

Course Objectives

At the end of the course, the student will be able to:
CO1: Explain the principles of cryogenic engineering, cryogenic properties of fluids, and thermodynamic processes associated with cryogenic systems.
CO2: Analyse cryogenic fluid storage, transfer systems, insulation techniques, and boil-off characteristics for aerospace applications.
CO3: Evaluate the design and performance of cryogenic pumps, valves, heat exchangers, and turbomachinery used in cryogenic propulsion systems.
CO4: Analyse the operating principles and performance characteristics of cryogenic rocket engines, propellant feed systems, and combustion processes.
CO5: Assess recent advances, safety aspects, and emerging technologies in cryogenic propulsion systems for aerospace applications.

Module-1

Fundamentals of Cryogenic Engineering

Introduction to Cryogenic Engineering – Definition and applications of cryogenics – Properties of cryogenic fluids (Liquid Hydrogen, Liquid Oxygen, Liquid Nitrogen and Liquid Helium) – Thermodynamic properties at cryogenic temperatures – Joule–Thomson effect – Claude and Linde liquefaction cycles – Cryogenic refrigeration principles – Applications of cryogenics in aerospace, space exploration, medical, energy and industrial sectors.

Flipped Class Content: Cryogenic fluids and liquefaction processes used in aerospace applications.

Number of Hours:08

Module-2

Cryogenic Fluid Storage and Transfer Systems

Cryogenic storage systems – Dewar vessels – Double-walled vacuum insulated tanks – Thermal insulation techniques (vacuum insulation, multilayer insulation, powder insulation and foam insulation) – Boil-off phenomenon and reduction methods – Cryogenic fluid transfer systems – Transfer lines – Valves – Pressure build-up systems – Instrumentation for cryogenic storage and handling.

Flipped Class Content: Design and operation of cryogenic storage tanks and transfer systems.

Number of Hours:08

Module-3

Cryogenic Components and Turbomachinery

Cryogenic pumps – Cryogenic valves – Heat exchangers – Vaporizers – Expanders – Turbo pumps for cryogenic rocket propulsion – Materials for cryogenic applications – Mechanical behaviour of materials at cryogenic temperatures – Sealing techniques – Reliability and performance characteristics of cryogenic components.

Flipped Class Content: Materials and turbomachinery used in cryogenic propulsion systems.

Number of Hours:08

Module-4
Cryogenic Rocket Engines and Propulsion Systems Introduction to cryogenic propulsion – Cryogenic propellants – Engine feed systems – Combustion chamber – Injector systems – Regenerative cooling – Turbopump-fed engines – Gas generator cycle – Staged combustion cycle – Expander cycle – Performance parameters – Specific impulse – Thrust coefficient – Performance analysis of cryogenic rocket engines – Overview of indigenous and international cryogenic launch vehicle propulsion systems. **Flipped Class Content**: Working principles and performance analysis of cryogenic rocket engines. Number of Hours:10
Module-5
Advanced Cryogenic Technologies and Aerospace Applications Safety aspects in cryogenic systems – Handling of cryogenic propellants – Hazard identification and risk mitigation – Recent developments in reusable cryogenic propulsion – Green cryogenic propellants – Cryogenic technology for launch vehicles, upper stages and deep-space missions – Emerging trends in cryogenic engineering – Future research directions. **Flipped Class Content:** Emerging cryogenic propulsion technologies for future launch vehicles and space missions. Number of Hours:08

Textbooks:

1. Barron, R. F., Cryogenic Systems, 2nd Edition, Oxford University Press, 1985.
2. Timmerhaus, K. D. and Flynn, T. M., Cryogenic Process Engineering, Springer Science & Business Media, 1989.
3. Sutton, G. P. and Biblarz, O., Rocket Propulsion Elements, 9th Edition, John Wiley & Sons, 2017.

Reference books / Manuals:

1. Flynn, T. M., Cryogenic Engineering, 2nd Edition, CRC Press, 2004.
2. Van Sciver, S. W., Helium Cryogenics, 2nd Edition, Springer, 2012.
3. Huzel, D. K. and Huang, D. H., Modern Engineering for Design of Liquid-Propellant Rocket Engines, American Institute of Aeronautics and Astronautics (AIAA), 1992.

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1. Problem -based learning
2. Use modelling and simulation techniques / virtual labs
3. Project-based learning
4. Student-led seminars

Web links and Video Lectures (e-Resources):

1. https://nptel.ac.in/courses/112101004
2. https://www.isro.gov.in/LPSC/
3. https://ocw.mit.edu/courses/16-512-rocket-propulsion-fall-2005/
4. https://www.isro.gov.in/ISRO_EN/RLVTD_Launchers/

Assessment Structure:

The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks**.
- To pass the **SEE**, a student must score at least **35% of 50 marks**, i.e., **18 marks**.

Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE** is at least **40 out of 100 marks**.

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of **two Internal Assessment Tests(IA)** shall be conducted, carrying a total of **25 marks**.

In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks**.

It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development of students**. These activities shall be:

Sl. No.	Name of the Learning activity	Maximum Marks
1	Case Study / Mini-project / Research paper Review / Simulation Challenges etc.	25

Continuous Internal Evaluation (CIE)

(i)The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.

(ii)Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.

(iii) The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.

(iv) A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE

For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.

For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.

If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade 'F' (Fail).

ELECTRIC AND HYBRID PROPULSION SYSTEMS			
Course Code	1MAS204	Scheme	2026
Type of Course	PCC	Semester	II
Teaching Hours/Week (L:T:P)	3:0:0	CIE Marks	50
Total Hours of Pedagogy L /T/P/SL&TW:	90(42 : 0 : 0 : 48)	SEE Marks	50
Credits	03	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	03

Course Objectives

At the end of the course, the student will be able to:

CO1: Explain the environmental impact, fundamentals, performance parameters, and propulsion requirements of electric, hybrid electric, and fuel cell vehicles.

CO2: Analyse different electric vehicle configurations, traction motors, drive systems, energy consumption, and performance characteristics.

CO3: Describe hybrid electric vehicle architectures, operating modes, drivetrain concepts, and energy management strategies.

CO4: Evaluate various energy storage technologies, battery management systems, charging methods, and power electronic systems used in electric mobility.

CO5: Apply concepts of regenerative braking, fuel cell technology, vehicle control strategies, smart charging, and emerging trends in electric vehicle technologies.

Module-1

Introduction & Vehicle Fundamentals: Environmental impact of transportation, Air pollution, Global warming, Petroleum resources, History of EVs, HEVs & FCVs, Vehicle propulsion fundamentals, Vehicle resistance, Tractive effort, Vehicle performance

Number of Hours: 8

Module-2

Electric Vehicles & Propulsion Systems: EV configurations, Traction motor characteristics, Tractive effort and transmission requirements, EV performance, Energy consumption, DC motor drives, Induction motor drives, BLDC motor drives, SRM drives

Number of Hours: 8

Module-3

Hybrid Electric Vehicles: Hybrid drivetrain concepts, Series hybrid, Parallel hybrid, Series–parallel hybrid, Plug-in hybrid vehicles, Mild hybrid vehicles, Operating modes, Energy management strategies, Hybrid transmission

Number of Hours: 8

Module-4

Energy Storage Systems: Electrochemical batteries, Battery technologies, Lithium-ion batteries, Ultracapacitors, Flywheel energy storage, Hybrid energy storage systems, Battery Management System (BMS), Charging methods, Power electronics

Number of Hours: 8

Module-5

Regenerative Braking & Advanced Technologies: Fundamentals of regenerative braking, Brake system of EV/HEV/FCV, Regenerative braking control, Fuel cell vehicles, Hydrogen energy systems, Vehicle control strategies, Smart charging, Vehicle-to-Grid (V2G), Future trends in electric mobility

Number of Hours: 8

Textbooks:

1. Mehrdad Ehsani, Yimi Gao, Sebastian E. Gay, Ali Emadi, Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design, CRC Press, 2004.

Reference books / Manuals:

1. Iqbal Hussein, Electric and Hybrid Vehicles: Design Fundamentals, CRC Press, 2003.
2. James Larminie, John Lowry, Electric Vehicle Technology Explained, Wiley, 2003.

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1. Case-based learning
2. Conceptual challenges and discussions
3. Virtual labs
4. Mission-based learning

Web links and Video Lectures (e-Resources):

1. https://www.nasa.gov/glenn/
2. https://www.nasa.gov/mission/eap/
3. https://www.easa.europa.eu/en/light/topics/sustainable-aviation-towards-zero-emission-aviation/
4. https://www.sae.org/standards/

Assessment Structure:

The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks**.
- To pass the **SEE**, a student must score at least **35% of 50 marks**, i.e., **18 marks**.

Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE** is at least **40 out of 100 marks**.

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of **two Internal Assessment Tests(IA)** shall be conducted, carrying a total of **25 marks**.

In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks**.

It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development of students**. These activities shall be:

Sl. No.	Name of the Learning activity	Maximum Marks
1	Case Study / Mini-project / Research paper Review / Quizzes / Assignments etc.	25

Continuous Internal Evaluation (CIE)

(i)The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.

(ii)Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.

(iii) The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.

(iv) A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE

For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.

For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.

If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade 'F' (Fail).

SYSTEM ENGINEERING APPROACH TO PROPULSION			
Course Code	1MAS205A	Scheme	2026
Type of Course	PEC	Semester	II
Teaching Hours/Week (L:T:P)	3: 0: 0	CIE Marks	50
Total Hours of Pedagogy L /T/P/SL&TW:	90(42 : 0 : 0 : 48)	SEE Marks	50
Credits	03	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	03

Course Objectives

At the end of the course, the student will be able to:
CO1: Explain the systems engineering lifecycle, stakeholder requirements, and the fundamentals of aerospace propulsion systems used in aircraft and space applications.
CO2: Develop system requirements, functional architectures, and interface definitions for integrated aerospace propulsion systems considering installation and operational constraints.
CO3: Analyse propulsion system performance using thermodynamic modelling, mission analysis, and design trade-off studies to support engineering decision-making.
CO4: Evaluate propulsion system reliability, safety, certification requirements, and lifecycle considerations using engineering risk assessment techniques.
CO5: Design verification and validation strategies for integrated propulsion systems using systems engineering principles, MBSE concepts, and real-world aerospace case studies.

Module-1

Introduction to Systems Engineering for Propulsion

Systems engineering lifecycle, stakeholder requirements, functional analysis, top-down and bottom-up approaches; overview of propulsion system types (turbofan, turbojet, turboprop, rocket, electric propulsion).

Number of Hours: 8

Module-2

Requirements, Functional Architectures and Interfaces

Requirement elicitation and validation, performance and environment requirements; system architecture, subsystem decomposition (airframe–propulsion integration), interface control documents; mass, balance, and installation constraints.

Number of Hours: 8

Module-3

Modelling, Design Trade-offs and Optimization

Propulsion system performance modelling (thermodynamic cycle, propulsion maps), mission analysis and sizing, multi-disciplinary optimization, sensitivity and trade studies, use of surrogate models and design tools.

Number of Hours: 8

Module-4

Reliability, Safety, Risk & Certification

Reliability and maintainability modelling (MTBF/MTTR), fault tree and FMEA analysis, safety assessment, hazard analysis, certification processes (airworthiness, environmental regulations), lifecycle cost and logistics considerations.

Number of Hours: 8

Module-5

Integration, Verification, Validation and Case Studies

System integration and test planning, hardware-in-the-loop, model-based systems engineering (MBSE) tools, verification and validation strategies, case studies: turbofan integration on transport aircraft, rocket stage systems engineering, propulsion upgrade projects.

Number of Hours: 8

Textbooks:

1. P. M. Waterhouse, "Systems Engineering for Aerospace: A Practitioner's Guide".
2. M. Biagiotti and A. G. Hamedani, "Aircraft Propulsion Systems Technology and Integration".
3. B. P. L. Thomson, "Systems Engineering Principles and Practice" (INCOSE).

Reference books / Manuals:

1. ARP4754A, INCOSE Handbook.
2. FAA/ EASA certification guidance material.
3. J. D. Anderson, "Fundamentals of Aerodynamics" (selected chapters on propulsion integration).

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1. Digital-model based System Engineering exercises
2. Case-based learning using Real Propulsion systems
3. Design review simulation activities
4. Conduct of workshops

Web links and Video Lectures (e-Resources):

1. https://www.nasa.gov/reference/systems-engineering-handbook/
2. https://www.nasa.gov/centers-and-facilities/glenn/electric-propulsion-and-power-laboratory/
3. https://nptel.ac.in/courses/110104074
4. https://www.youtube.com/playlist?list=PLUl4u3cNGP60jIMmB53zl6awCKMnABhYx

Assessment Structure:

The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks**.
- To pass the **SEE**, a student must score at least **35% of 50 marks**, i.e., **18 marks**.

Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE** is at least **40 out of 100 marks**.

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of **two Internal Assessment Tests(IA)** shall be conducted, carrying a total of **25 marks**.

In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks**.

It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development of students**. These activities shall be:

Sl. No.	Name of the Learning activity	Maximum Marks
1	Case Study / Mini-project / Research paper Review / Quizzes / Assignments etc.	25

Continuous Internal Evaluation (CIE)

(i)The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.

(ii)Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.

(iii) The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.

(iv) A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE

For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.

For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.

If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade 'F' (Fail).

OPTIMIZATION TECHNIQUES IN AEROSPACE PROPULSION			
Course Code	1MAS205B	Scheme	2026
Type of Course	PEC	Semester	II
Teaching Hours/Week (L:T:P)	3: 0: 0	CIE Marks	50
Total Hours of Pedagogy L /T/P/SL&TW:	90(42 : 0 : 0 : 48)	SEE Marks	50
Credits	03	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	03

Course Objectives

At the end of the course, the student will be able to:
CO1: Formulate aerospace propulsion design and analysis problems as constrained optimization problems.
CO2: Apply gradient-based and non-gradient-based optimization methods to propulsion system design.
CO3: Evaluate and implement evolutionary and multi-objective optimization techniques for propulsion applications.
CO4: Analyse the effects of uncertainty and employ surrogate modelling techniques for complex propulsion optimization problems.
CO5: Apply multidisciplinary design optimization approaches to advanced aerospace propulsion systems.

Module-1

Introduction to optimization in aerospace engineering, Classification of optimization problems, Design variables, objective functions, constraints, Single-objective and multi-objective optimization, Convex and non-convex optimization problems, Optimality criteria and Kuhn-Tucker conditions, Sensitivity analysis, Formulation of propulsion optimization problems **Applications:** Thrust optimization, Specific impulse maximization, Fuel consumption minimization, Weight optimization of propulsion systems

Number of Hours: 09

Module-2

Unconstrained optimization methods, Steepest descent method, Conjugate gradient method, Newton and Quasi-Newton methods, Constrained optimization techniques, Penalty function methods, Sequential Quadratic Programming (SQP), Interior-point methods, Adjoint-based optimization, Sensitivity derivatives in propulsion design

Applications: Compressor and turbine blade optimization, Rocket nozzle contour optimization, Combustor design optimization

Number of Hours: 09

Module-3

Genetic Algorithms (GA), Differential Evolution (DE), Particle Swarm Optimization (PSO), Simulated Annealing (SA), Multi-objective optimization concepts, Pareto optimality and Pareto fronts, NSGA-II and NSGA-III algorithms, Hybrid optimization strategies

Applications: Turbofan cycle optimization, Rocket propulsion parameter optimization, Emission and performance trade-off analysis

Number of Hours: 08

Module-4

Design of Experiments (DOE), Response Surface Methodology (RSM), Kriging and Gaussian Process models, Radial Basis Function approximation, Bayesian optimization, Uncertainty Quantification (UQ), Reliability-Based Design Optimization (RBDO), Robust optimization methods

Applications: CFD-assisted propulsion optimization, Turbine performance prediction, Propulsion reliability assessment

Number of Hours: 08

Module-5

Introduction to Multidisciplinary Design Optimization (MDO), MDO architectures: MDF, IDF, Collaborative Optimization, Aero-thermo-structural optimization, Gas turbine engine cycle optimization, Rocket propulsion system optimization, Electric and hybrid-electric propulsion optimization, AI and Machine Learning applications in propulsion optimization, Digital twin-based propulsion design optimization

Applications: Sustainable aviation propulsion systems, Reusable launch vehicle propulsion systems, Next-generation aircraft engine design

Number of Hours: 08

Textbooks:

1. Engineering Optimization: Theory and Practice, S. S. Rao, 5th Edition, Wiley, 2019.
2. Engineering Design Optimization, Joaquim R. R. A. Martins and Andrew Ning, Cambridge University Press, 2021.
3. Numerical Optimization, Jorge Nocedal and Stephen Wright, Springer, 2006.
4. Multi-Objective Optimization Using Evolutionary Algorithms, Wiley, 2001**.**

Reference books / Manuals:

1. Aircraft Engine Design, AIAA Education Series.
2. Elements of Gas Turbine Propulsion, McGraw-Hill.
3. Rocket Propulsion Elements, Wiley.
4. Jet Propulsion, Cambridge University Press.
5. Mechanics and Thermodynamics of Propulsion, Pearson Education.

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1. Digital-model based System Engineering exercises
2. Case-based learning using Real Propulsion systems
3. Design review simulation activities
4. Conduct of workshops

Web links and Video Lectures (e-Resources):

1. https://www.youtube.com/watch?v=BMdLYXKZZtE&list=PLyqSpQzTE6M8XNc8SxMLbUxdR7lDSuIGw
2. https://www.nptel.ac.in/courses/111105039/
3. https://www.youtube.com/watch?v=Li5WZOeFeUQ&list=PLe7H9pun_r8YHoGv0TnYxUsgbj0xAJmMR

Assessment Structure:

The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks**.
- To pass the **SEE**, a student must score at least **35% of 50 marks**, i.e., **18 marks**.

Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE** is at least **40 out of 100 marks**.

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of **two Internal Assessment Tests(IA)** shall be conducted, carrying a total of **25 marks**.

In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks**.

It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development of students**. These activities shall be:

Sl. No.	Name of the Learning activity	Maximum Marks
1	Case Study / Mini-project / Research paper Review / Quizzes / Assignments etc.	25

Continuous Internal Evaluation (CIE)

(i)The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.

(ii)Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.

(iii) The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.

(iv) A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE

For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.

For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.

If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade ‘F’ (Fail).

MULTIPHASE FLOW AND ATOMIZATION			
Course Code	1MAS205C	Scheme	2026
Type of Course	PEC	Semester	II
Teaching Hours/Week (L:T:P)	3: 0: 0	CIE Marks	50
Total Hours of Pedagogy L /T/P/SL&TW:	90(42 : 0 : 0 : 48)	SEE Marks	50
Credits	03	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	03

Course Objectives

At the end of the course, the student will be able to:
CO1: Explain the fundamentals of multiphase flows and their governing equations.
CO2: Apply interphase momentum, heat, and mass transfer principles in multiphase flows.
CO3: Analyse dispersed phase behaviour using population balance and CFD models.
CO4: Evaluate atomization, droplet breakup, and spray characterization techniques.
CO5: Develop multiphase flow models for engineering applications.

Module-1

Fundamentals of Multiphase Flows

Flow regimes and classification, continuum vs discrete phase approaches; volume of fluid (VOF) and mixture models; conservation equations for phases; averaged equations and closure issues.

Number of Hours: 9

Module-2

Interphase Momentum, Mass and Heat Transfer

Drag, lift, virtual mass forces, added mass, buoyancy; heat and mass transfer correlations for droplets and particles; evaporation and condensation models; droplet heating and lifetime.

Number of Hours: 9

Module-3

Population Balance and Dispersed Phase Modelling

Population balance equation (PBE), methods of moments, sectional and Monte Carlo approaches, coalescence and breakup kernels, coupling PBE to CFD.

Number of Hours: 8

Module-4

Atomization and Breakup Mechanics

Primary atomization mechanisms (instability-driven, shear, aerodynamic); secondary breakup regimes (Weber number dependence), Taylor–Rayleigh, Kelvin–Helmholtz, Rayleigh–Taylor instabilities; empirical and mechanistic models for droplet size distribution.

Number of Hours: 8

Module-5

Applications and Experimental/Computational Methods

Spray diagnostics, measurement techniques (PDPA, Phase Doppler, high-speed imaging), cavitation and bubble dynamics, fluidized beds, nuclear/chemical reactor multiphase issues; coupling to engine combustor modeling and atomizer design; validation and case studies.

Number of Hours: 8

Textbooks:

1. C. K. Li and S. Sundaresan, "Multiphase Flows: Theory and Numerics" (selected materials).
2. A. Lefebvre and D. R. Ballal, "Gas Turbine Combustion: Alternative Fuels and Emissions" (chapters on sprays).
3. D. C. Crowe, J. D. Schwarzkopf, M. Sommerfeld, Y. Tsuji, "Multiphase Flows with Droplets and Particles".

Reference books / Manuals:

1. G. S. Settles, "Schlieren and Shadowgraph Techniques" (experimental visualization).
2. H. K. Versteeg & W. Malalasekera (relevant chapters on multiphase modelling).
3. Journal review articles on atomization (e.g., Lefebvre review papers).

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1. CFD-based virtual laboratories
2. Image based learning
3. Problem-based aerospace case studies
4. Flipped classroom

Web links and Video Lectures (e-Resources):

1. https://www.youtube.com/watch?v=Q1C2aokCRyc&list=PL9MU15T40v3A0Fgi3ESUm_yps8PM5tt8J
2. https://learninghub.ansys.com/learn/courses/479/ansys-fluent-multiphase-flow-modeling/
3. https://learninghub.ansys.com/learn/courses/479/ansys-fluent-multiphase-flow-modeling/
4. https://nptel.ac.in/courses/103105058/

Assessment Structure:

The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks**.
- To pass the **SEE**, a student must score at least **35% of 50 marks**, i.e., **18 marks**.

Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE** is at least **40 out of 100 marks**.

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of **two Internal Assessment Tests(IA)** shall be conducted, carrying a total of **25 marks**.

In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks**.

It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development of students**. These activities shall be:

Sl. No.	Name of the Learning activity	Maximum Marks
1	Case Study / Mini-project / Research paper Review / Quizzes / Assignments etc.	25

Continuous Internal Evaluation (CIE)

(i)The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.

(ii)Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.

(iii) The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.

(iv) A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE

For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.

For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.

If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade ‘F’ (Fail).

STRUCTURAL DYNAMICS OF PROPULSION SYSTEMS			
Course Code	1MAS205D	Scheme	2026
Type of Course	PEC	Semester	II
Teaching Hours/Week (L:T:P)	3: 0: 0	CIE Marks	50
Total Hours of Pedagogy L /T/P/SL&TW:	90(42 : 0 : 0 : 48)	SEE Marks	50
Credits	03	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	03

Course Objectives

At the end of the course, the student will be able to:
CO1: Explain the principles of liquid rocket engines and the role of structural dynamics in their design, analysis, testing, and operation.
CO2: Apply vibration theory, modal analysis, and finite element methods to evaluate the dynamic behaviour of rocket engine structures.
CO3: Analyse the structural dynamic response of rocket engine components, including turbopumps, combustion devices, and nozzles.
CO4: Evaluate engine system loads, fluid–structure interactions, and vibration-induced failures affecting liquid rocket engine performance.
CO5: Assess structural dynamic testing methods and validation techniques for improving the reliability and safety of liquid rocket engines.

Module-1

Introduction to Structural Dynamics of Liquid Rocket Engines: Introduction to liquid rocket engines (LRE), overview of propulsion system architecture, role of structural dynamics in design, analysis, testing and operation, dynamic failures in rocket engines, vibration sources, engine loads, interaction between structural dynamics, stress analysis, rotor dynamics and fluid-structure interaction, case studies of historical engine failures.

Number of Hours: 09

Module-2

Fundamentals of Structural Dynamics: Review of vibration theory, single and multi-degree-of-freedom systems, free and forced vibrations, damping, modal analysis, frequency response, finite element modelling, modal superposition, transient and random vibration analysis, modal testing and dynamic boundary conditions.

Number of Hours: 08

Module-3

Structural Dynamics of Rocket Engine Components: Structural dynamics of turbopumps, excitation mechanisms, high-cycle fatigue, Campbell diagrams, cyclic symmetry, mistuning effects, damping in turbomachinery, forced response analysis, structural dynamics of combustion devices, injectors and rocket nozzles, nozzle side-load phenomena and resonance mitigation.

Number of Hours: 09

Module-4

Engine System Loads and Fluid–Structure Interaction: Rocket engine system loads, dynamic environments, load characterization, harmonic and random loading, engine load combinations, propellant feedlines, vortex shedding, cavitation, fluid-induced vibration, structural assessment of system hardware, lessons learned from engine load failures.

Number of Hours: 08

Module-5

Testing, Validation and Advanced Topics: Modal testing, hot-fire testing, qualification and acceptance testing, whirligig testing, validation of structural dynamic models, advanced structural dynamics topics, multidisciplinary interactions, emerging challenges and future directions in liquid rocket engine structural dynamics.

Number of Hours: 08

Textbooks:

1. Andrew M. Brown, Structural Dynamics of Liquid Rocket Engines: A Holistic Approach, Springer Nature, Synthesis Lectures on Mechanical Engineering, 2022.
2. Daniel J. Inman, Engineering Vibration, 5th Edition, Pearson Education, 2022.
3. Leonard Meirovitch, Fundamentals of Vibrations, McGraw-Hill Education, 2001.

Reference books / Manuals:

1. George P. Sutton and Oscar Biblarz, Rocket Propulsion Elements, 9th Edition, John Wiley & Sons, 2017.
2. Arthur W. Leissa and Mohamad S. Qatu, Vibrations of Continuous Systems, McGraw-Hill Education, 2011.
3. Singiresu S. Rao, Mechanical Vibrations, 6th Edition, Pearson Education, 2018.
4. William T. Thomson and Marie Dillon Dahleh, Theory of Vibration with Applications, 5th Edition, Pearson Education, 1998.

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1. Experimental learning – hands-on experience in vibration measurement and signal interpretation
2. Case-based learning using instances of engine failures
3. Virtual lab experiments

Web links and Video Lectures (e-Resources):

1. https://www.nptel.ac.in/courses/105102688/
2. https://learninghub.ansys.com/learn/courses/101/ansys-mechanical-rotordynamics/
3. https://www.nasa.gov/eap-labs-and-testbeds/dynamic-spin-rig/

Assessment Structure:

The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks**.
- To pass the **SEE**, a student must score at least **35% of 50 marks**, i.e., **18 marks**.

Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE** is at least **40 out of 100 marks**.

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of **two Internal Assessment Tests(IA)** shall be conducted, carrying a total of **25 marks**.

In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks**.

It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development of students**. These activities shall be:

Sl. No.	Name of the Learning activity	Maximum Marks
1	Case Study / Mini-project / Research paper Review / Quizzes / Assignments etc.	25

Continuous Internal Evaluation (CIE)

(i)The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.

(ii)Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.

(iii) The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.

(iv) A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE

For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.

For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.

If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade ‘F’ (Fail).

ADVANCED COMBUSTION			
Course Code	1MAS206A	Scheme	2026
Type of Course	PEC	Semester	II
Teaching Hours/Week (L:T:P)	3: 0: 0	CIE Marks	50
Total Hours of Pedagogy L /T/P/SL&TW:	90(42 : 0 : 0 : 48)	SEE Marks	50
Credits	03	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	03

Course Objectives

At the end of the course, the student will be able to:
CO1: Explain the principles of jet propulsion systems and gas turbines.
CO2: Analyse ideal and actual gas turbine cycles.
CO3: Explain the operation and performance of compressors.
CO4: Analyse the performance of impulse and reaction turbines.
CO5: Describe turbine blade cooling, materials, and environmental aspects.

Module-1

Jet propulsion cycles and analysis: Introduction, Prime movers, simple gas turbine, energy equation, Dimensional analysis of rotating machine, Ram jet engine, pulse jet engine, turboprop engine, turbojet engine, thrust and thrust equation, specific thrust of turbojet engine, efficiencies, parameters affecting performance, thrust augmentation, problems.

Number of Hours:9

Module-2

Ideal cycles and their analysis: Introduction, assumptions, Brayton Cycle, reheat cycle, reheat and regenerator, inter cooled cycle with heat exchanger, inter cooled and reheat cycle, comparison of varies cycles, Ericsson cycle, compressor and turbine efficiency, performance of actual cycle.

Number of Hours:8

Module-3

Centrifugal and axial flow compressors: Essential parts of centrifugal and axial flow compressors, principles of operation, blade shape and velocity triangles, performance characteristics, surging and chocking, degree of reaction, compressor stage efficiency, and mechanical loses, problems.

Number of Hours:9

Module-4

Impulse and reaction turbine: single impulse stage and reaction stage, velocity triangles of a single stage machines, expression for work output, blade and stage efficiencies, velocity and pressure compounding, multi stage reaction turbines, performance graphs, losses and efficiencies.

Number of Hours:8

Module-5

Blade materials, cooling and environmental consideration: Blade materials, manufacturing techniques, blade fixing, blade cooling, liquid cooling, air cooling, practical air cooled blades, NOX formation, noise standards, noise reduction, aircraft emission standards

Number of Hours:8

Textbooks:

1. Gas turbines - V Ganesan Tata McGraw-Hill Publishing company limited.
2. Gas turbine theory - H.I.H Saravanamuttoo, G.F.C. Rogers and H. Cohen PV Straznicky, Publisher: Pearson Education Canada.

Reference books / Manuals:

1. Mechanics & Thermodynamics of Propulsion - Hill, P.G. & Peterson, C.R. Addison – Wesley Longman INC, 1999
2. Aerospace Propulsion - Dennis G Shepherd, American Elsevier Publishing Co Inc NY.
3. Aircraft Gas Turbine Engine Technology, 3rd Edition - E. Irwin Treager, 1995 ISBN- 002018281

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1. CFD-based laboratory (virtual)
2. Use of digital twin concept
3. AI/ML-based techniques
4. Flipped classroom with Research papers

Web links and Video Lectures (e-Resources):

1. https://learninghub.ansys.com/learn/courses/160/ansys-fluent-combustion-modeling/
2. https://onlinecourses.nptel.ac.in/e-learning/preview/noc22_me97
3. https://nptel.ac.in/courses/101104014/
4. https://www.youtube.com/watch?v=TxABeIO-Px0&list=PLbInEHTmP9VYSWy1-rIE_Brl3xSVY5LEC

Assessment Structure:

The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks**.
- To pass the **SEE**, a student must score at least **35% of 50 marks**, i.e., **18 marks**.

Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE** is at least **40 out of 100 marks**.

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of **two Internal Assessment Tests(IA)** shall be conducted, carrying a total of **25 marks**.

In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks**.

It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development of students**. These activities shall be:

Sl. No.	Name of the Learning activity	Maximum Marks
1	Case Study / Mini-project / Research paper Review / Quizzes / Assignments etc.	25

Continuous Internal Evaluation (CIE)

(i)The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.

(ii)Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.

(iii) The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.

(iv) A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE

For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.

For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.

If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade ‘F’ (Fail).

MECHANICAL ASPECTS OF ROTATING MACHINERY			
Course Code	1MAS206B	Scheme	2026
Type of Course	PEC	Semester	II
Teaching Hours/Week (L:T:P)	3: 0: 0	CIE Marks	50
Total Hours of Pedagogy L /T/P/SL&TW:	90(42 : 0 : 0 : 48)	SEE Marks	50
Credits	03	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	03

Course Objectives

At the end of the course, the student will be able to:

CO1: Explain the fundamentals of rotating machinery, vibration sources, and vibration measurement techniques in aero engines.

CO2: Analyse vibration characteristics, natural frequencies, critical speeds, and dynamic response of rotor systems.

CO3: Assess fatigue, creep, and failure mechanisms in gas turbine engine components.

CO4: Evaluate rotor imbalance, bearing performance, lubrication systems, and sealing techniques used in aero engines.

CO5: Apply engine inspection, fault diagnosis, and noise control methods for rotating machinery maintenance.

Module-1

Introduction: Definition of a rotating machinery, parts of a rotating machinery w.r.t different aero engine configurations namely like turboprop, turbo shaft, turbojet and turbo fan. Basic issues in rotating machinery like vibrations, unbalance, casing rub and oil debris. Vibration: An overview of basics of vibrations and their significance in rotating machinery, Sources of vibrations in rotating machinery and its characterization. Vibration isolators, vibration measurement, sensors and analysis, industrial standards for vibration

Number of Hours: 8

Module-2

Analytical modelling and solution for vibration: Single DOF systems, free vibration, un-damped and viscously damped cases. Forced vibration, impulse and Fourier excitation. Response spectra, and modal frequency response, one & two degrees of freedom system. General multi-DOF systems including stiffness, flexibility and mass matrices. Natural frequencies and mode shapes (Eigen values and Eigen vectors), Coupled modes.

Energy methods: Lagrange's equations, Application to rotor- shaft systems, Branched gear- shaft systems, Rigid body modes, Continuous (distributed parameter) systems. Critical Speeds and Response to Imbalance: Classical whirl, Coriolis effects, Euler angles, Coriolis matrix, Quadratic Eigen value problem solution, Campbell diagrams.

Number of Hours: 10

Module-3

Fatigue and creep: Definition of fatigue and creep, creep and fatigue in gas turbine components, low and high cycle fatigue, life estimation of turbine blades estimation for creep, typical examples of gas turbine components failure due to creep and fatigue

Number of Hours: 8

Module-4

Imbalance characterization in engines: Rigid and flexible rotors, impact of unbalance on aero engine performance, sources of unbalance, single and multi-plane balancing, Shaft Alignment, Balancing standards for rotating machinery in industries. Bearings, Lubrication and Seals: Types of bearings in aero engines, Load and life evaluation of aircraft engine bearings, lubrication and its characterization. Application of magnetic and foil bearings in aero engines, Different types of seals used in aero engines.

Number of Hours: 8

Module-5

Engine noise and Inspection: Shaft and casing stiffness measurement and methods for control, Measurement of noise, sources of noise generation and methods for noise reduction, Various methods for inspecting Engine rotating component including non-destructive methods and CMM. Engine fault diagnosis and tools

Number of Hours: 8

Textbooks:

1. Theory of Vibration with Applications, William T. Thomson, 5th Edition, Prentice Hall, 1997.
2. Rotor Dynamics Prediction in Engineering, Michel Lalanne and Guy Ferraris, John Wiley & Sons, 1998.

Reference books / Manuals:

1. Engineering Vibration, Daniel J. Inman, Prentice Hall, 3rd Edition, 2007.
2. Vibration Problems in Engineering, Stephen P. Timoshenko et al., Wolfenden Press, 2008.
3. Rotor Dynamics of Turbomachinery, John M. Vance, John Wiley & Sons (Wiley-Interscience), 1988.
4. Rotating Machinery Vibration, Maurice L. Adams, CRC Press, 2000.

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1. Flipped classroom
2. Facilitate conduct of Hands-on sessions related to condition monitoring
3. Case-based learning
4. Use basic ML techniques to classify machine health and predict possible failures.

Web links and Video Lectures (e-Resources):

1. https://www.youtube.com/watch?v=Ajtgd3jf9TI&list=PLiLi0iBi4Dwxt-UAJaEiWTBEWvK69c6Na
2. https://www.youtube.com/@RotorDynamics
3. https://nptel.ac.in/courses/108105131

Assessment Structure:

The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks**.
- To pass the **SEE**, a student must score at least **35% of 50 marks**, i.e., **18 marks**.

Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE** is at least **40 out of 100 marks**.

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of **two Internal Assessment Tests(IA)** shall be conducted, carrying a total of **25 marks**.

In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks**.

It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development of students**. These activities shall be:

Sl. No.	Name of the Learning activity	Maximum Marks
1	Case Study / Mini-project / Research paper Review / Quizzes / Assignments etc.	25

Continuous Internal Evaluation (CIE)

(i)The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.

(ii)Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.

(iii) The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.

(iv) A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE

For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.

For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.

If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade 'F' (Fail).

ENGINE HEALTH MONITORING AND DIAGNOSTICS			
Course Code	1MAS206C	Scheme	2026
Type of Course	PEC	Semester	II
Teaching Hours/Week (L:T:P)	3: 0: 0	CIE Marks	50
Total Hours of Pedagogy L /T/P/SL&TW:	90(42 : 0 : 0 : 48)	SEE Marks	50
Credits	03	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	03

Course Objectives

At the end of the course, the student will be able to:
CO1: Explain the principles and architecture of engineering health monitoring systems.
CO2: Select appropriate sensors and instrumentation for propulsion system condition monitoring.
CO3: Analyse engineering signals to identify faults in rotating and propulsion machinery.
CO4: Apply prognostic and machine learning techniques for health assessment and remaining useful life prediction.
CO5: Evaluate integrated health monitoring systems and digital twin applications for aerospace propulsion.

Module-1

Fundamentals of Engineering Health Monitoring: Introduction to Health Monitoring (HM), Condition Monitoring (CM), Fault Detection and Diagnostics (FDD), Prognostics and Health Management (PHM); maintenance philosophies—reactive, preventive, predictive and condition-based maintenance; reliability, availability and maintainability (RAM); failure modes, failure mechanisms and fault classification; health monitoring architecture for aerospace propulsion systems; overview of gas turbine engine health monitoring.

Number of Hours: 08

Module-2

Sensors, Instrumentation and Data Acquisition: Sensors for health monitoring: vibration, temperature, pressure, strain, speed, displacement, acoustic emission and oil debris sensors; sensor placement strategies; data acquisition systems; signal conditioning; sampling theory; data quality, calibration and uncertainty; onboard engine monitoring systems and aerospace instrumentation standards.

Number of Hours: 09

Module-3

Signal Processing and Fault Diagnostics: Time-domain, frequency-domain and time-frequency analysis; FFT, STFT and wavelet transform; vibration signature analysis; order tracking; envelope analysis; acoustic and thermal diagnostics; fault diagnosis of bearings, gears, shafts, compressors, turbines and combustion systems; lubrication and wear debris analysis.

Number of Hours: 09

Module-4

Prognostics and Data-Driven Health Monitoring: Feature extraction and feature selection; statistical process monitoring; anomaly detection; Remaining Useful Life (RUL) estimation; machine learning techniques for fault diagnosis—Artificial Neural Networks (ANN), Support Vector Machines (SVM), Decision Trees and Random Forests; introduction to deep learning for predictive maintenance; data fusion techniques.

Number of Hours: 08

Module-5

Integrated Engine Health Monitoring and Digital Twins: Engine Health Management (EHM) systems; integrated vehicle health management (IVHM); digital twins for aerospace propulsion; model-based diagnostics; fault-tolerant control concepts; case studies on aircraft engines, helicopter transmissions, rocket propulsion systems and industrial gas turbines; future trends in smart maintenance and Industry 4.0.

Number of Hours: 08

Textbooks:

1. Engineering Condition Monitoring: Practice, Methods and Applications, Butterworth-Heinemann, 2002.
2. Machinery Condition Monitoring: Principles and Practices, Chapman & Hall, 1998.
3. Practical Machinery Vibration Analysis and Predictive Maintenance, Elsevier, 2004.

Reference books / Manuals:

1. Gas Turbine Diagnostics: Signal Processing and Fault Isolation, IET Publications.
2. Machine Learning: A Probabilistic Perspective, MIT Press, 2012.
3. Engine Health Management: Concepts and Practices.

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1. Provide engine sensor datasets to students to support execution of AI/ML based diagnostic projects
2. Problem-based learning
3. Introduce fault injection experiments
4. Flipped classroom technique

Web links and Video Lectures (e-Resources):

1. https://www.geaerospace.com/collaborative-insight
2. https://www.youtube.com/watch?v=7rKjN-wK83s&list=PLSGws_74K019n5sjannZRKcSpG25beMLl
3. https://genaviationsupport.com/engine-health-monitoring-in-aviation-from-sensor-data-to-predictive-intelligence/

Assessment Structure:

The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks**.
- To pass the **SEE**, a student must score at least **35% of 50 marks**, i.e., **18 marks**.

Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE** is at least **40 out of 100 marks**.

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of **two Internal Assessment Tests(IA)** shall be conducted, carrying a total of **25 marks**.

In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks**.

It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development of students**. These activities shall be:

Sl. No.	Name of the Learning activity	Maximum Marks
1	Case Study / Mini-project / Research paper Review / Quizzes / Assignments etc.	25

Continuous Internal Evaluation (CIE)

(i)The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.

(ii)Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.

(iii) The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.

(iv) A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE

For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.

For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.

If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade ‘F’ (Fail).

HYPERSONIC PROPULSION AND HIGH-SPEED AIR-BREATHING ENGINES			
Course Code	1MAS206D	Scheme	2026
Type of Course	PEC IV	Semester	II
Teaching Hours/Week (L:T:P)	3: 0: 0	CIE Marks	50
Total Hours of Pedagogy L /T/P/SL&TW:	90(42 : 0 : 0 : 48)	SEE Marks	50
Credits	03	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	03

Course Objectives

At the end of the course, the student will be able to:
CO1: Explain the fundamentals of high-speed flight and hypersonic propulsion systems.
CO2: Analyse hypersonic aerothermodynamics, shock waves, and inlet performance.
CO3: Describe the operating principles and performance of ramjet and scramjet engines.
CO4: Evaluate the design and thermodynamic performance of high-speed propulsion systems.
CO5: Discuss advanced hypersonic propulsion technologies and their aerospace applications.

Module-1

Introduction: Fundamentals of high-speed flight, evolution of air-breathing propulsion systems, atmospheric flight regimes, classification of high-speed propulsion systems, turbojet, turbofan, ramjet, scramjet and combined-cycle engines. Applications in missiles, reusable launch vehicles, hypersonic cruise vehicles and space access systems. Flight Mach number regimes, propulsion requirements, performance parameters, specific impulse, thrust generation mechanisms, propulsion-airframe integration, overview of global and Indian hypersonic technology development programs.

Number of Hours:08

Module-2

Hypersonic Aerothermodynamics and Inlet Systems: Fundamentals of compressible flow, normal and oblique shock waves, expansion waves, shock-shock and shock-boundary layer interactions, hypersonic flow characteristics, high-temperature gas effects, real gas phenomena, viscous interactions, aerodynamic heating and thermal loads. Hypersonic Aerothermodynamics and Inlet Systems: Fundamentals of compressible flow, normal and oblique shock waves, expansion waves, shock-shock and shock-boundary layer interactions, hypersonic flow characteristics, high-temperature gas effects, real gas phenomena, viscous interactions, aerodynamic heating and thermal loads. Supersonic and hypersonic air intakes, inlet compression processes, mixed-compression and external-compression inlets, inlet starting and unstarting phenomena, inlet performance parameters, inlet design methodologies, flow distortion and boundary layer control. hypersonic air intakes, inlet compression processes, mixed-compression and external-compression inlets, inlet starting and unstarting phenomena, inlet performance parameters, inlet design methodologies, flow distortion and boundary layer control.

Number of Hours:08

Module-3

Ramjet and Scramjet Propulsion Systems: Ramjet engine fundamentals, operating principles, combustion processes in ramjets, fuel injection techniques, flame stabilization methods, performance analysis and limitations. Scramjet propulsion principles, supersonic combustion mechanisms, fuel-air mixing processes, combustor configurations, ignition and flame holding, hydrogen and hydrocarbon fuels for scramjets, combustion efficiency, thermal choking, scramjet performance characteristics, propulsion system integration and operational challenges.

Number of Hours:08

Module-4

High-Speed Engine Design and Performance Analysis: Thermodynamic cycle analysis of ramjet and scramjet engines, ideal and real cycle performance, propulsion efficiency, thrust and specific impulse calculations, engine sizing methodologies, combustor design concepts, nozzle design for hypersonic propulsion systems, expansion processes, variable geometry systems, cooling techniques, regenerative cooling, fuel management systems, computational methods for performance prediction, propulsion-airframe integration and vehicle performance optimization.

Number of Hours:09

Module-5

Advanced Hypersonic Propulsion Technologies and Applications: Combined-cycle propulsion systems, turbo-ramjet and turbo-scramjet engines, rocket-based combined cycle (RBCC) engines, turbine-based combined cycle (TBCC) engines, dual-mode ramjet/scramjet engines, reusable hypersonic vehicles, air-breathing access-to-space concepts, thermal protection systems, materials for hypersonic propulsion, experimental facilities and ground testing, flight testing methodologies, current research trends, autonomous hypersonic vehicles, future challenges and emerging technologies in hypersonic propulsion.

Number of Hours:09

Textbooks:

1. Heiser, W.H. and Pratt, D.T., Hypersonic Airbreathing Propulsion, AIAA Education Series.
2. Curran, E.T. and Murthy, S.N.B., Scramjet Propulsion, AIAA Progress in Astronautics and Aeronautics.
3. Hill, P.G. and Peterson, C.R., Mechanics and Thermodynamics of Propulsion.
4. Mattingly, J.D., Elements of Propulsion: Gas Turbines and Rockets.
5. Sutton, G.P. and Biblarz, O., Rocket Propulsion Elements.

Reference books / Manuals:

1. Anderson, J.D., Hypersonic and High Temperature Gas Dynamics.
2. Anderson, J.D., Modern Compressible Flow with Historical Perspective.
3. Curran, E.T., High-Speed Flight Propulsion Systems.
4. Sforza, P.M., Theory of Aerospace Propulsion.
5. Segal, C., The Scramjet Engine: Processes and Characteristics.
6. Oates, G.C., Aerothermodynamics of Gas Turbine and Rocket Propulsion.

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1. Virtual Hypersonic engine laboratory
2. Use case studies related to real high speed propulsion systems such as scramjets, ramjets etc.
3. Use Digital twin concepts
4. Use of AI/ML tools

Web links and Video Lectures (e-Resources):

1. https://ntrs.nasa.gov/
2. https://www.nasa.gov/hypersonics/
3. https://arc.aiaa.org/
4. https://www.academia.edu/Documents/in/Hypersonic_Air-breathing_Propulsion

Assessment Structure:
The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks**.
- To pass the **SEE**, a student must score at least **35% of 50 marks**, i.e., **18 marks**.

Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE** is at least **40 out of 100 marks**.

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of **two Internal Assessment Tests(IA)** shall be conducted, carrying a total of **25 marks**.

In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks**.

It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development of students**. These activities shall be:

Sl. No.	Name of the Learning activity	Maximum Marks
1	Case Study / Mini-project / Research paper Review / Quizzes / Assignments etc.	25

Continuous Internal Evaluation (CIE)
(i)The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.
(ii)Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.
(iii) The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.
(iv) A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE
For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.
For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.
If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade ‘F’ (Fail).

COMPUTATIONAL FLUID DYNAMICS LAB			
Course Code	1MASL207	Scheme	2026
Type of course	Professional Core Course Lab	Semester	II
Teaching Hours/Week (L:T:P)	0 : 0 : 2	CIE Marks	50
Total Hours of Pedagogy L:T:P:SL:TW	30 (00 : 00 : 28 : 02)	SEE Marks	50
Credits	01	Total Marks	100
Type of Examination	Practical	Exam Hours	03

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:
CO1: Develop grids around given shapes and transform the physical domain in to computational domain
CO2: Develop adaptive structured and unstructured grids
CO3: Apply knowledge to solve CFD problems through finite difference and finite volume techniques and Analyse using available fluid flow software.

Note:

1. The laboratory syllabus consists of PART-A and PART-B. While PART-A has 6-8 conventional experiments, PART-B has 6 typical open-ended experiments. The maximum marks for the laboratory course are 100.
2. Both PART-A and PART-B are considered for CIE and SEE.
3. Students have answer 1(one) question from PART-A and 1(one) question from PART-B.
   a. The questions set for SEE shall be from among the experiments under PART-A. It is evaluated for **80 marks** out of the maximum 100 marks.
   b. The open-ended question set for SEE shall be any other open-ended question and not selected from the experiments under PART-A. It shall be evaluated for **20 marks.**

For Continuous Internal Evaluation (CIE) during the semester, classwork shall typically include open-ended questions from **Part-B**, along with other similar questions designed to enhance the students' skills.

PART – A
List of experiments

1. Laminar Flow over a flat plate and determination of flow variables.
2. Turbulent Flow over a flat plate and determination of flow variables.
3. Flow over an airfoil and computation of basic flow variables (velocities and pressure).
4. Computation of flow parameter in a Convergent & Convergent-Divergent nozzle using commercially available software.
5. Computation of Fluid Flow variables in a cascade of blades using commercially available software.
6. Computations of Flow variables in a compressor/turbine stage using commercially available software

PART – B
OPEN ENDED EXPERIMENTS

Open-ended experiments are a type of laboratory activity where the outcome is not predetermined and students are given the freedom to explore, design, and conduct the experiment based on the problem statements as per the concepts defined by the course coordinator. It encourages creativity, critical thinking, and inquiry-based learning.

1. Experiment on One-dimensional heat conduction and computation of different parameters.
2. Computation of one-dimensional conduction-convection mode of heat transfer using

commercially available software.

3. Computation in a quasi-steady Rotor-Stator Interaction using commercially available software.
4. Computational Fluid dynamics in any one Industrial example relevant to aerospace propulsion technology using commercially available software.
5. Basic concepts and computation in multiphase flow in propulsion using commercially available software.
6. Computations of flow variables in combustion modelling in a gas turbine propulsion system using commercially available software.

Textbooks/Manuals:

1. Computational Fluid Dynamics Lab Manual.

Web links and Video Lectures (e-Resources):

- https://www.youtube.com/playlist?list=PLOHR3aasYKTn8PIRPJwA8T3az59-ThS6n
- https://www.youtube.com/watch?v=NlLy-u61yyk

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for a pass in the course.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject /course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation (CIE):

For the Professional Core Course Laboratory, the maximum marks prescribed are 100. Out of these, 50 marks are allotted for Continuous Internal Evaluation (CIE) and 100 marks for the Semester End Examination (SEE). The SEE marks obtained out of 100 shall be proportionately scaled down to 50 marks. The final result shall be declared based on the aggregate of the CIE marks (50) and the scaled-down SEE marks (50), totalling 100 marks."

Out of 50 marks, 40 marks shall be assigned for assessment of regular laboratory PART -A classwork, and 10 marks for Part – B. (Table 1)

Out of 40 marks, 25 marks shall be based on the regular classwork and allotment of marks shall be as per rubrics listed in Table 1.

The remaining 15 marks shall be based on the practical test conducted by two Internal examiners appointed by the HoD. The allotment of marks shall be as per the rubrics defined for the practical test as indicated in the Table 1.

The open-ended question set for CIE shall be any other open-ended question and not selected from the experiments under PART-A. It shall be evaluated for 10 marks. The allotment of marks shall be as per rubrics listed in Table 2

Table – 1 Distribution of marks corresponding to laboratory component		
Component	**Description**	**Marks**
Allotment of marks for regular classwork		
Ability in Conducting Experiments	Initiative, skill, safety practices, teamwork, and independent handling of equipment during regular lab sessions.	10 marks
Laboratory Record / Journal	Regular and neat maintenance of lab record, accuracy of results, and timely submission.	15 marks
	Subtotal	**25**
Allotment of marks for CIE practical test		
Laboratory Test / Experiment Performance	Ability to set up apparatus, follow procedure, take observations, and obtain correct results in the test experiment.	5 marks
Viva-Voce	Understanding of theory, concepts, and experimental procedure; ability to explain results and answer related questions.	10marks
	Subtotal	**15**
	Total	**40**

Table 2 Distribution of marks corresponding to PART -B of the laboratory component				
Evaluation Rubrics for continuous internal evaluation CIE). Maximum marks:10				
Criteria and Guiding factors	**Students' Level and Rubrics**			
	Excellent: E, Good: G, Fair: F Needs Improvements: NI			
	E	**G**	**F**	**NI**
(1) Problem Understanding **Criteria:** Is the problem understood correctly and framed appropriately? (i)Clarity in interpreting the given problem. (ii)Identification of relevant concepts and constraints. (iii) Ability to rephrase or model the problem logically.	2.0	1.5	1.0	0.5
(2) Conceptual Knowledge **Criteria**: Are the chosen methods or concepts valid for this type of problem? (i)Application of appropriate theories, principles, or laws. (ii)Integration of multiple concepts where necessary. (iii)Accuracy in stating relevant equations or models.	2.0	1.5	1.0	0.5
(3) Approach and Strategy **Criteria**: Is the approach well thought out and methodical? (i)Logical structure and progression. (ii)Use of diagrams, sketches, or flowcharts if	2.0	1.5	1.0	0.5

applicable. (iii)Identification of assumptions and boundary conditions.				
(4) Execution and Accuracy **Criteria**: Are the calculations correct? Is the final solution reasonable? (i) Correct application of formulas/methods. (ii)Accuracy of calculations or simulations (if any). (iii)Unit consistency and result verification.	2.0	1.5	1.0	0.5
(5) Innovation or Depth **Criteria**: Has the student shown original thinking or alternative methods? (i)Novel or efficient solutions. (ii)Consideration of alternate approaches. (iii)Interdisciplinary integration or practical extensions.	1	0.75	0.5	0.25
(6) Presentation and Clarity **Criteria**: Is the answer easy to follow and professionally written? (i)Organization and neatness. (ii)Clarity of explanation, labelling, and steps. (iii) Use of proper technical terminology.	1	0.75	0.5	0.25
Total	10	7.5	5.0	2.5

Note:
(i)The marks shown for *Excellent, Good, Fair, Needs Improvement* are indicative. The evaluator may also assign intermediate scores depending on the quality of work.
(ii)If the total score results in a fraction, it should be rounded off to the next higher integer.
(iii)The listed criteria are guidelines; evaluators may also consider other authentic dimensions (e.g., depth of insight, critical thinking, and practical awareness, recognition of limitations, or justified compromises.
(iv)To award the full10 marks in the excellent category, the student must demonstrate reasonably good performance across all six criteria; otherwise, proportionally lower marks may be given.

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