Appendix - II (G)

M. Tech Degree (Full Time) Programme

in

MECHANICAL ENGINEERING

(Specialization: Aerospace Propulsion)

SCHEME OF EXAMINATION & SYLLABUS

SCHOOL OF ENGINEERING
COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY
COCHIN– 682 022

JULY – 2024

DIVISION OF MECHANICAL ENGINEERING

VISION

The Mechanical Engineering Division strives to be recognized globally for outstanding education and research leading to well-qualified engineers, who are innovative, entrepreneurial and successful in advanced fields of engineering and research

MISSION

- Imparting quality education to the students an enhancing their skills to make them globally competitive mechanical engineers.
- Maintaining vital, state-of-the-art research facilities to provide its students and faculty with opportunities to create, interpret, apply and disseminate knowledge.
- To develop linkages with world class R&D organizations and educational institutions in India and abroad for excellence in teaching, research and consultancy practices.

PROGRAMME EDUCATIONAL OBJECTIVES

PEO1	To prepare students to excel in postgraduate programmes or to succeed in industry/technical profession through global rigorous education.
PEO2	To provide students with a solid foundation in mathematical, scientific and engineering fundamentals required to solve engineering problems and also to pursue higher studies.
PEO3	To train students with good scientific and engineering breadth so as to comprehend, analyze, design and create novel products and solutions for the real life problems.
PEO4	To inculcate in students professional and ethical attitude, effective communication skills, team work skills, multidisciplinary approach and an ability to relate engineering issues to broader social context.
PEO5	To provide student with an academic environment aware of excellence, leadership, written ethical codes and guidelines, and the life-long learning needed for a successful professional career.

PROGRAMME OUTCOMES

On completion of the programme the graduate will

PO1: Be able to independently carry out research/investigation and developmental work to solve practical problems.

PO2: Attain an ability to write and present substantial technical reports/documents.

PO3: Attain mastery over the various areas under the purview of aerospace engineering.

PO4: Be able to use modern engineering tools, softwares and equipments to analyse various safety problems encountered in industries and society.

PO5: Be able to work effectively in teams to develop efficient solutions to the problems in industries and society.

PO6: Be able to maintain a high level of professional ethics, intellectual integrity and scholarly standards.

PEO-PO Mapping

PO / PEO	PO1	PO2	PO3	PO4	PO5	PO6
PEO1	2	2	2	2	2	1
PEO2	2	2	2	2	2	2
PEO3	2	2	2	3	2	2
PEO4	2	1	2	1	3	2
PEO5	2	2	2	1	1	2

1-Slightly, 2- Moderately, 3-Substantially

M. Tech Degree (Full Time) Programme in Mechanical Engineering

(Specialisation: Aerospace Propulsion)

SEMESTER I						
Sl No.	Course Code	Course Name	Hours/Week			Credits
			L	T	P	
1	24-508-0101	Aerodynamics of Flight Vehicles	3	1	0	4
2	24-508-0102	Advanced Gas Dynamics	3	1	0	4
3	24-508-0103	Flight Mechanics	3	1	0	4
4	24-508-01**	Elective I (MOOC)	0	0	0	3
5	24-508-01**	Elective II	3	1	0	3
6	24-508-0112	Research Methodology & IPR	2	1	0	2
7	24-508-0113	Propulsion Laboratory	0	0	3	1
8	24-508-0114	Seminar I	0	0	3	1
Total			14	5	6	**22**

SEMESTER II						
Sl No.	Course Code	Course Name	Hours/Week			Credits
			L	T	P	
1	24-508-0201	Air Breathing Propulsion	3	1	0	4
2	24-508-0202	Rocket Propulsion	3	1	0	4
3	24-508-0203	Computational Fluid Dynamics	3	1	0	4
4	24-508-02**	Elective III	3	1	0	3
5	24-508-02**	Elective IV	3	1	0	3
6	24-508-0213	Computational Analysis Laboratory	0	0	3	1
7	24-508-0214	Seminar II	0	0	3	1
Total			15	5	6	**20**

SEMESTER III						
Sl No.	Course Code	Course Name	Hours/Week			Credits
			L	T	P	
1	24-508-0301	Internship/MOOC Course/Mini Project	0	0	6	2
2	24-508-0302	Project Dissertation Phase – I	0	0	24	13
Total			0	0	30	**15**

SEMESTER IV						
Sl No.	Course Code	Course Name	Hours/Week			Credits
			L	T	P	
1	24-508-0401	Project Dissertation Phase – II	0	0	30	15
Total			0	0	30	**15**

Total credits – 22 + 20 + 15 + 15 = **72**

ELECTIVE I (MOOC) (Semester I)
(Course Code: 24-508-0104 to 24-508-0107)
The broad area of MOOC

24-508-0104	Introduction to Turbulence
24-508-0105	Non-destructive Testing Techniques
24-508-0106	Computational Methods in Engineering
24-508-0107	Advanced Fluid Mechanics

ELECTIVE II (Semester I)

24-508-0108	Aerodynamics of Compressors and Turbines
24-508-0109	Introduction to Aircraft Design
24-508-0110	Space Flight Dynamics
24-508-0111	Advanced Thermodynamics

ELECTIVE III & IV (Semester II)

24-508-0204	Hypersonic Flows
24-508-0205	Computational Heat Transfer & Fluid Flow
24-508-0206	Finite Element Analysis
24-508-0207	Introduction to Combustion
24-508-0208	Principles of Turbo machinery
24-508-0209	Aeroacoustics
24-508-0210	Advanced Heat Transfer
24-508-0211	Convection and Two-Phase Flows
24-508-0212	Aerospace Materials

SYLLABUS FOR

M. TECH DEGREE PROGRAMME IN MECHANICAL ENGINEERING

(Specialisation: Aerospace Propulsion)

SEMESTER – I

24-508-0101: AERODYNAMICS OF FLIGHT VEHICLES

Course Outcomes:

On completion of this course the student will be able to:

CO1. *Understand the governing equations for aerodynamics*
CO2. *Apply the differential and integral forms of governing equations*
CO3. *Analyse shock cell interactions in supersonic flows*
CO4. *Analyse the effect of laminar boundary layer and skin friction*
CO5. *Evaluate effect of compressibility on skin friction and heat transfer*
CO6. *Explore flow instabilities and transition to turbulent flows*

Course Articulation Matrix

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	2	1	1
CO2	3	2	3	2	1	1
CO3	3	2	3	2	1	1
CO4	3	2	3	2	1	1
CO5	3	2	3	2	1	1
CO6	3	2	3	2	1	1

1: Low 2: Moderate 3. Highly related

Module I

Aerodynamic characteristics of airfoils and flow around finite wings - Circulation, irrotational flow, Stokes theorem, velocity potential, point vortex, vortex filament, Biot and Savart law, bound vortex, Kutta condition; Vortex sheet, Vortex sheet in thin-airfoil theory, Planar wing, Properties of symmetrical airfoil, Properties of cambered airfoil, Flapped airfoil, Finite Wing : Flow fields around finite wings, Downwash and induced drag, Fundamental equations of finite-wing theory, Elliptical lift distribution, Arbitrary circulation distribution, Twisted wing: Basic and Additional lift, Approximate calculation of additional lift, Winglets.

Module II

Airfoils, wings and wing-body combinations in compressible flow - Compressible flow field, Mach waves, normal shock wave, oblique shock waves, Prandtl-Meyer flow; Linearized Compressible Flow: Flow equation for small perturbations, steady supersonic flows, pressure coefficient for small perturbations; Airfoils in compressible flows: Boundary conditions, Airfoils in subsonic flow: Prandtl-Glauert transformation, Critical Mach number, Airfoils in transonic flow, Airfoils in supersonic flow; Wings and bodies in compressible flows: Prandtl-Glauert-Goethert transformation, Influence of sweepback, Design rules for wing-fuselage combinations.

Module III

Laminar boundary layer in compressible flow - Viscous boundary layer, boundary layer equation of motion, Conservation of energy in the boundary layer, Rotation and entropy gradient in the boundary layer, Similarity considerations for compressible boundary layers, Solution of energy equation for Prandtl number unity, Temperature recovery factor, Heat transfer versus skin friction, Velocity and temperature profiles and skin friction, Effects of pressure gradient.

Module IV

Flow instabilities and transition from laminar to turbulent flow, and turbulent flows - Gross effects, Reynolds experiment, Tollmien-Schlichting instability and transition, Natural laminar flow and laminar flow control, Stability of vortex sheets, Stratified flows, Transition phenomenon, Methods for experimentally detecting transition, Flow around spheres and circular cylinders Turbulent Flows: Description of turbulent field, Statistical properties, Conservation equations, Laminar sub-layer, Fully developed flows in tubes and channels, Constant-pressure turbulent boundary layer, Turbulent drag reduction, Effects of pressure gradient, Stratford criterion for turbulent separation, Effects of compressibility on skin friction, Reynolds analogy: Heat transfer and temperature recovery factor, Free turbulent shear flows.

References

1. Anderson, Fundamentals of aerodynamics, 5 ed., McGraw Hill, 2010.
2. Bertin & Cummings, Aerodynamics for engineers, 6 ed. Pearson, 2013.
3. Kuethe & Chow, Foundations of aerodynamics, 5 ed., John Wiley, 1998.
4. Ashley & Landahl, Aerodynamics of wings & bodies, Dover, 1985.
5. Houghton, Carpenter, Collicott & Valentine, Aerodynamics for engineering students, (6 ed.), Elsevier, 2013.
6. Talay, Introduction to the aerodynamics of flight, NASA SP-367, 1975.

24-508-0102: ADVANCED GAS DYNAMICS

Course Outcomes:

On completion of this course the student will be able to:

CO1. *Understand the Reynolds and Favre averaging of momentum equations in gas dynamics*
CO2. *Apply the differential forms of governing equations in isentropic flows*
CO3. *Apply the concept of normal and oblique shocks and analyse shock interactions*
CO4. *Analyse the generation of expansion waves in under and over expanded flows*
CO5. *Evaluate combination flows emerging from Isentropic, Fanno and Rayleigh flows*
CO6. *Explore the characteristics of high temperature flows and low density flows*

Course Articulation Matrix

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	2	1	1
CO2	3	2	3	2	1	1
CO3	3	2	3	2	1	1

CO4	3	2	3	2	1	1
CO5	3	2	3	2	1	1
CO6	3	2	3	2	1	1

1: Low 2: Moderate 3. Highly related

Module I

Concept of a fluid, Variation of viscosity with temperature, Differential relations for fluid flow - Continuity equation, Momentum equation, Navier Stokes equation, Reynolds averaging, Favre averaging, RANS equation, Mass and Momentum equation for fluctuating quantities.
Isentropic flow: Steady flow energy equation, Stagnation and critical states, Acoustic wave propagation speed, Isentropic flow with variable area, Maximum mass flow rate, Geometric choking in Convergent nozzle and Convergent Divergent nozzle.

Module II

Normal Shocks: Governing equations, Normal shock wave relations, Stationary and moving normal shock waves, Method of characteristics and design of nozzles.
Oblique Shocks and Expansion waves: Fundamental relations, θ-β-M diagram, Shock Reflections and Interactions, Detached shocks, Expansion of supersonic flow, Supersonic flow around a convex corner, Prandtl Meyer angle.
Imperfectly expanded flows: Under expanded and over expanded flows, Properties of slip line, Shock expansion theory, Calculation of lift and drag coefficients, Shock diamonds.

Module III

Fanno flow: Adiabatic flow in constant area duct with friction, Friction choking and its consequences, Variation of Mach number with duct length, Effect of duct length with maximum possible duct length, Combination of isentropic flows with Fanno flows.
Rayleigh flow: Frictionless flow in constant area duct with heat transfer, Thermal choking and its consequences, Maximum heat transfer. Effect of heat transfer with maximum possible heat transfer, Combination of isentropic flows with Rayleigh flows.

Module IV

High temperature flows: Introduction, Effect of temperature on specific heats, Perfect gas laws, Dissociation and Ionization, Nonequilibrium effects, Hypersonic flows, Newtonian theory, Aerodynamic heating - Recovery temperature and heat transfer rates.
Low density flows: Introduction, Knudsen number, Low density flow regimes, Slip flow, Free molecular flow.

References

1. Shapiro A. H., The Dynamics and Thermodynamics of Compressible Flow, Ronald Press Company, New York, 1953.
2. John D Anderson, Hypersonic and High Temperature Gas Dynamics, American Institute of Aeronautics and Astronautics, 2nd edition, 2006.
3. Babu V., Fundamentals of Gas dynamics, Ane publishers, New Delhi, 2007.
4. John D Anderson, Modern Compressible Flow, Mc Graw Hill, 2003.
5. Biswas and Eswaran, Turbulent Flows, Narosa Publishers. 2002.
6. James John and Theo Keith, Gas Dynamics, Pearson Education, 2006.
7. Patrick H Oosthuizen, W E Carscallen, Compressible Fluid Flow, Mc. Graw Hill, 1997.

24-508-0103: FLIGHT MECHANICS

Course Outcomes:

On completion of this course the student will be able to:

CO1. *Understand the conditions for minimum drag and power requirement*
CO2. *Apply equations and determine the range and endurance of an aircraft*
CO3. *Analyse take off and landing performance of aircrafts*
CO4. *Analyse climbing and turning performance of aircraft*
CO5. *Evaluate static longitudinal stability of aircrafts*
CO6. *Explore directional and dynamic stability of aircrafts*

Course Articulation Matrix

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	2	1	1
CO2	3	2	3	2	1	1
CO3	3	2	3	2	1	1
CO4	3	2	3	2	1	1
CO5	3	2	3	2	1	1
CO6	3	2	3	2	1	1

1: Low 2: Moderate 3. Highly related

Module I

Cruising flight performance: Forces and moments acting on a flight vehicle - Equation of motion of a rigid flight vehicle - Different types of drag – estimation of parasite drag co-efficient by proper area method - Drag polar of vehicles from low speed to high speeds - Variation of thrust, power with velocity and altitudes for air breathing engines. Performance of airplane in level flight - Power available and power required curves. Maximum speed in level flight - Conditions for minimum drag and power required.

Module II

Manoeuvering flight performance: Range and endurance - Climbing and gliding flight (Maximum rate of climb and steepest angle of climb, minimum rate of sink and shallowest angle of glide) – Take off and landing - Turning performance (Turning rate turn radius). Bank angle and load factor – limitations on turn - V-n diagram and load factor.

Module III

Static longitudinal stability: Degree of freedom of rigid bodies in space - Static and dynamic stability - Purpose of controls in airplanes -Inherently stable and marginal stable airplanes – Static, Longitudinal stability - Stick fixed stability - Basic equilibrium equation - Stability criterion - Effects of fuselage and nacelle - Influence of CG location - Power effects - Stick fixed neutral point - Stick free stability - Hinge moment coefficient - Stick free neutral points- Symmetric manoeuvres - Stick force gradients - Stick force per '*g*' - Aerodynamic balancing.

Module IV

Lateral and directional stability: Dihedral effect - Lateral control - Coupling between rolling and yawing moments - Adverse yaw effects - Aileron reversal - Static directional stability - Weather cocking effect - Rudder requirements - One engine inoperative condition - Rudder lock.

Dynamic stability: Introduction to dynamic longitudinal stability: - Modes of stability, effect of freeing the stick - Brief description of lateral and directional. dynamic stability - Spiral, divergence, Dutch roll, auto rotation and spin.

References

1. Mc Cormick. W., Aerodynamics, Aeronautics and Flight Mechanics, John Wiley, NY, 1979.
2. Nelson, R.C. "Flight Stability and Automatic Control", McGraw-Hill Book Co., 2004.
3. Perkins, C.D., and Hage, R.E., Airplane Performance stability and Control, John Wiley & Son:, Inc, NY, 1988.
4. Babister, A.W., Aircraft Dynamic Stability and Response, Pergamon Press, Oxford, 1980.
5. Dommasch, D.O., Sherby, S.S., and Connolly, T.F., Aeroplane Aerodynamics, Third Edition, Issac Pitman, London, 1981.
6. Etkin, B., Dynamics of Flight Stability and Control, Edn. 2, John Wiley, NY, 1982.
7. Mc. Cornick B. W, Aerodynamics, Aeronautics and Flight Mechanics, John Wiley, NY, 1995.

ELECTIVE I (MOOC)

24-508-0104: INTRODUCTION TO TURBULENCE

Course Outcomes:

On completion of this course the student will be able to:

CO1. *Understand the ubiquitous nature of turbulence*
CO2. *Solve scales in turbulence and Navier Stokes equation*
CO3. *Analyse vorticity dynamics and anisotropy in turbulence*
CO4. *Evaluate Reynolds stresses and explore closure problem in turbulence*
CO5. *Apply different forms of turbulence models*
CO6. *Explore the features of direct numerical simulation, large eddy simulation and RANS simulations*

Course Articulation Matrix

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	2	1	1
CO2	3	2	3	2	1	1
CO3	3	2	3	2	1	1
CO4	3	2	3	2	1	1
CO5	3	2	3	2	1	1
CO6	3	2	3	2	1	1

1: Low 2: Moderate 3. Highly related

Module I

Ubiquitous nature of turbulence – the experiments of Taylor and Benard, flow over a cylinder, Reynolds experiment, ubiquitous nature of turbulence, different scales in turbulent flow, Kolmogorov scales, closure problem of turbulence, Navier stokes equation, molecular diffusion, turbulent eddy diffusion.

Module II
Rate of dissipation of energy in viscous fluid, Vorticity dynamics, Kelvins theorem, vorticity and angular momentum, isotropic and anisotropic turbulence, Origin and nature of turbulence.

Module III
Turbulent shear flows and simple closure models, Reynolds stress and closure problem of turbulence, Prandtl mixing length, Boussinesq approximation, transfer of energy from the mean flow to the turbulence, k-epsilon, k-omega models, wall bounded shear flows and log-law of the wall, turbulence boundary layer, coherent structures, planar jets and wakes, round jets.

Module IV
Reynolds stress model, time and length scales in turbulence, turbulent diffusion, direct numerical simulation, Large eddy simulation, Reynolds averaging, density based averaging, velocity correlation.

References

1. Wilcox, Introduction to turbulence, DCW Industries, 1993.
2. Davidson P. A., Introduction to Turbulence, Oxford, 2004.
3. Tennekes and Lumley, Introduction to turbulence, MIT Press, 1972.
4. Biswas andEaswaran, Turbulent Flows – Fundamentals, Experiments and Modeling, Narosa Publishing Company, 2002.

24-508-0105: NON-DESTRUCTIVE TESTING TECHNIQUES

Course Outcomes:
On completion of this course the student will be able to:
CO1. *Understand the principles of non-destructive testing (NDT) techniques*
CO2. *Evaluate and select appropriate NDT methods for different materials and applications*
CO3. *Perform NDT inspections using various techniques*
CO4. *Analyse and interpret NDT results for defect detection and characterization*
CO5. *Evaluate acoustic emission techniques*
CO6. *Explore the methods of stressing and fringe analysis*

Course Articulation Matrix

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	2	1	1
CO2	3	2	3	2	1	1
CO3	3	2	3	2	1	1
CO4	3	2	3	2	1	1
CO5	3	2	3	2	1	1
CO6	3	2	3	2	1	1

1: Low 2: Moderate 3. Highly related

Module I

Introduction to Non-destructive Testing: Definition and importance of non-destructive testing. Classification of NDT methods: Visual Inspection and Penetrant Testing: Basics of visual inspection and its applications. Penetrant testing principles and techniques. Magnetic particle testing principles. Techniques and equipment used in magnetic particle testing.

Ultrasonic Testing: Nature of sound waves, wave propagation in metals– modes of sound wave generation – longitudinal, transverse, surface, and lamb waves –Velocity, frequency and wavelength of ultrasonic waves – Ultrasonic pressure, intensity and impedance – Attenuation of ultrasonic waves – reflection, refraction and mode convection – Snell's law and critical angles – Fresnel and Fraunhofer effects , Principle of pulse echo method, through transmission method, resonance method – Advantages, limitations – contact testing, immersion testing, couplants – Data presentation A, B and C scan displays, comparison of contact and immersion method.

Module II

Eddy Current Testing: Generation of eddy currents – effect of change of impedance on instrumentation – properties of eddy currents – eddy current sensing elements, probes, type of coil arrangement Factors affecting sensing elements and coil impedance - test part and test system – Signal to noise ratio.

Radiographic Testing: Basics of radiographic testing and its applications. Radiographic equipment and safety measures. Computed Tomography, X-Ray detectors – CT image reconstruction algorithm - capabilities, comparison to other NDT methods - industrial CT applications.

Module III

Principles of Thermography: Contact and non-contact inspection methods - Heat sensitive paints - Heat sensitive papers, calibration and sensitivity - non contact thermographic inspection - Advantages and limitations - infrared radiation and infrared detectors, Instrumentations and methods, pulsed thermography, eddy current thermography, applications.

Acoustic emission techniques: Principles of acoustic emission techniques, advantages and limitations - instrumentation applications, Acoustical Holography.

Module IV

Optical Holography and Speckle Metrology: Laser fundamentals, coherence, types of lasers, holography, recording and reconstruction, holographic interferometry, real-time, double-exposure & time- averaged techniques, holographic NDT, methods of stressing and fringe analysis, typical applications, requirements, advantages and disadvantages, laser speckle metrology basics, electronic speckle pattern interferometry (ESPI), shearography applications.

References

1. Shull, P. J., Non-destructive Evaluation: Theory, Techniques, and Applications, CRC Press, 2014.
2. Baldev Raj, T. Jayakumar, M. Thavasimuthu, Non-Destructive Testing and Quality Management, Narosa Publishing House, 2010.

3. J. Krautkramer and H. Krautkramer, Ultrasonic Testing of Materials, Springer, 4th edition 1990.
4. Xavier PV Maldague, "Nondestructive evaluation of materials by infrared thermography", Springer Science & Business Media, 2012.
5. Joseph L. Rose, "Ultrasonic Guided Waves in Solid Media", Cambridge University Press, 2014.
6. ASTM E1316-20, Standard Terminology for Non-destructive Examinations, ASTM International, 2020.
7. Michael, M., Introduction to Non-destructive Testing: A Training Guide, ASNT, 2017.
8. Raghav, S., Practical Non-Destructive Testing, Woodhead Publishing, 2018.
9. B.P.C. Rao, Practical Eddy Current Testing, Alpha Science International Limited, 2006.
10. Tribikram Kundu, Ultrasonic and electromagnetic NDE for structure and material characterization: Engineering and biomedical applications, CRC Press, 2016.
11. Lester Schmerr, Fundamentals of ultrasonic non-destructive evaluation, Springer, 2016.
12. Miller Ronnie and Paul Mclntire, Non-Destructive Testing Handbook; Acoustic Emission Testing, Vol. 5, 2nd Edition, Columbus, OH: American Society for Non-Destructive Testing, 2013.

24-508-0106: COMPUTATIONAL METHODS IN ENGINEERING

Course Outcomes:

On completion of this course the student will be able to:

CO1. *Apply computational methods in Engineering and Technology using CAS (Computer Algebra Systems)*

CO2. *Understand errors and their propagation and the measures to control errors in the application of computational methods*

CO3. *Apply numerical methods to solve linear algebra problems*

CO4. *Apply numerical methods for interpolation, differentiation, integration, and integral transforms*

CO5. *Understand ordinary and partial differential equations and apply finite difference (FDM) method to solve them*

CO6. *Understand calculus of variations and Finite Element Method (FEM). Apply FEM to solve Ordinary Differential Equations (ODE)*

Course Articulation Matrix

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	2	1	1
CO2	3	2	3	2	1	1
CO3	3	2	3	2	1	1
CO4	3	2	3	2	1	1
CO5	3	2	3	2	1	1
CO6	3	2	3	2	1	1

1: Low 2: Moderate 3. Highly related

Module I

Approximations: Accuracy and precision, definitions of round off and truncation errors, error propagation.

Introduction to CAS programs like Matlab/Mathematica/Maple/Python and their application to solve numerical examples of the topics included below.

Algebraic equations: Formulation and solution of linear algebraic equations, Gauss elimination, LU decomposition, iteration methods (Gauss – Siedel), convergence criteria, Eigen values and Eigen vectors.

Module II

Interpolation methods: Newton's divided difference, interpolation polynomials, Lagrange interpolation polynomials, Differentiation and Integration: High accuracy differentiation formulae, extrapolation, derivatives of unequally spaced data, Gauss quadrature and integration.

Transform techniques: Continuous Fourier series, frequency and time domains, Laplace transform, Fourier integral and transform, Discrete Fourier Transform (DFT), Fast Fourier Transform (FFT).

Module III

Differential equations: Initial and boundary value problems, Eigen value problems, Partial differential equations.

Numerical solutions differential equations: Formation of difference equations, types of difference equations and their solutions. Laplace and Poisson's equations. Iterative methods for solutions of parabolic, elliptic and hyperbolic types of Partial Differential Equations.

Module IV

Calculus of variations: Introduction to maxima and minima, variational notations, functional and Euler's equations, constraints and Lagrange multipliers, Hamiltonian Principles.

Finite Element theory: Introduction to finite element theory, generalization of finite element concept, variational approaches, steady state field problems such as heat conduction, electrical and magnetic potential, fluid flow, failure mechanics, etc.

References

1. Steven C Chapra, Applied Numerical Method with Matlab for Engineers and Scientists, McGraw-Hill, 2017.
2. Schilling R.J and Harris S. L, Applied Numerical Methods for Engineering using Matlab and C, Brooks/Cole Publishing Co., 2003.
3. S. S. Sastry, Introduction to Numerical Methods, Prentice-Hall, 1999.
4. Fon Sneddon, Introduction to Integral Transforms, McGraw Hill, 2016.
5. R. Forsythe, Calculus of Variation, CambridgeUniversity Press, 1927.
6. David V Hutton, Fundamentals of Finite Element Analysis, McGraw- Hill, 2003.
7. Gerald and Wheatley, Applied Numerical Analysis, Pearson Education, 1998.

24-508-0107: ADVANCED FLUID MECHANICS

Course Outcomes:

On completion of this course the student will be able to:

CO1. *Understand the basic concepts of fluid mechanics*

CO2. *Demonstrate lift and drag for flow past a cylinder with and without rotation*

CO3. *Analyse viscous incompressible flows between parallel plates, along pipes and around sphere*
CO4. *Evaluate boundary layer phenomena*
CO5. *Explore the control of boundary layer separation and transition*
CO6. *Solve turbulent boundary layer equations and determine the coherent structures in the wall layer*

Course Articulation Matrix

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	2	1	1
CO2	3	2	3	2	1	1
CO3	3	2	3	2	1	1
CO4	3	2	3	2	1	1
CO5	3	2	3	2	1	1
CO6	3	2	3	2	1	1

1: Low 2: Moderate 3. Highly related

Module I
Flow of ideal fluids: Introduction, Uniform flow, Source and Sink, Vortex flow, Doublet, Flow about a cylinder without circulation, Lift and drag for flow past a cylinder without circulation, Flow about a rotating cylinder, Lift and drag for flow about a rotating cylinder.

Module II
Viscous incompressible flows: Navier-Stokes Equations, Exact solutions of Navier–Stokes equations, Parallel flow in a straight channel, Couette flow between two parallel flat plates, Plane Poiseuille flow, Hagen Poiseuille flow through a pipe, Low Reynolds number flow around a sphere.

Module III
Laminar boundary layer: Boundary layer approximation and equations, Wall Shear and boundary layer thickness, Momentum – Integral equations for boundary layer, Separation of boundary layer, Entry flow in a duct, Control of boundary layer separation, Mechanism of boundary layer transition.

Module IV
Turbulent flow: Characteristics of turbulent flow, Reynolds Stresses, Turbulent flow near a wall, Turbulent boundary layers, Laminar – Turbulent transition, Turbulence production and cascade, Mean motion and fluctuations, Derivation of governing equations for turbulent flow, Turbulent boundary layer equations, Boussenesq approximation, Wall free shear flow, Wall bounded shear flow, Coherent structures in a wall layer.

References

1. Bachelor, G.K., An Introduction to Fluid Dynamics, London Cambridge University Press, 1967.
2. Shames, I. H., Mechanics of Fluids, McGraw Hill Book Company, New York, 1962.

3. Schlichting, H., Boundary Layer Theory, McGraw Hill Book Company, New York, 1953.
4. Mohanty, A. K., Fluid Mechanics, Prentice Hall of India Private Limited, New Delhi, 1986.
5. Som S.K., and Biswas G., Introduction to Fluid Mechanics & Fluid Machines, Tata McGraw Hill, 1998.
6. Frank M. White, Fluid Mechanics, Tata McGraw Hill, 1986.
7. Pijush K Kundu and Ira M. Cohen, Fluid Mechanics, Elsevier, 2001.
8. Tennekes H., and Lumley J. L., Introduction to Turbulence, MIT Press, 1972.
9. Biswas G., and Eswaran V., Turbulent flows, Narosa Publishing House, 2002.

ELECTIVE II

24-508-0108: AERODYNAMICS OF COMPRESSORS AND TURBINES

Course Outcomes:

On completion of this course the student will be able to:

CO1. *Understand working principle of axial flow compressors and its losses*
CO2. *Apply equations and determine axial compressor characteristics*
CO3. *Analyse instability and pressure loss in axial flow compressors*
CO4. *Evaluate work done and degree of reaction in axial flow turbines*
CO5. *Analyse surging and stall in centrifugal compressors*
CO6. *Explore conservation of rothalpy in turbo machines*

Course Articulation Matrix

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	2	1	1
CO2	3	2	3	2	1	1
CO3	3	2	3	2	1	1
CO4	3	2	3	2	1	1
CO5	3	2	3	2	1	1
CO6	3	2	3	2	1	1

1: Low 2: Moderate 3. Highly related

Module I

Introduction to Turbomachinery: Axial flow compressors and Fans; Aero-thermodynamics of flow through axial flow compressor stage; Losses in axial flow compressor stage; Losses and Blade performance estimation; Secondary flows (3-D); Tip leakage flow and scrubbing; 3-D flow analysis; Radial equilibrium equation.

Module II

Axial compressor characteristics; Design of compressor blades-2-D blade designs; Airfoil Data; Axial Flow Track Design; Multi-staging of compressor characteristics; Transonic Compressors; Shock Structure Models in Transonic Blades; Transonic Compressor

Characteristics; 3-D Blade shapes of Rotors and Stators; Instability in Axial Compressors; Loss of Pressure Rise; Loss of Stability Margin; Noise problems in axial compressors and fans.

Module III

Axial flow turbines: Turbine stage; Turbine Blade 2-D analysis; Work Done and Degree of Reaction; Losses and Efficiency; Flow Passage and flow track in multi-stage turbines; Subsonic, Transonic and Supersonic turbines; Multi-staging of Turbine; Exit flow conditions; Turbine blade cooling; Turbine Blade design – Turbine profiles; Airfoil data and Profile construction; 3-D blade design.

Module IV

Centrifugal Compressors: Introduction; Elements of centrifugal compressor/ fan; Inlet Duct ; Impeller flow; Effect of Slip factor; Concept of conservation of rothalpy in turbo machines; Ideal and real work done; Incidence and lag angles; Diffuser; Centrifugal Compressor Characteristics; Surging and Rotating stall; Design variants of modern centrifugal compressors; Radial Turbine: Introduction; Thermodynamics and Aerodynamics of radial turbines; Radial Turbine Characteristics; Losses and efficiency; Design of radial turbine; Use of CFD for Turbomachinery analysis and design.

References

1. Nicholas Cumpsty, Compressor Aerodynamics, 2004, Kreiger Publications, USA
2. Johnson I.A., Bullock R.O. NASA-SP-36, Axial Flow Compressors, 2002, NTIS, USA.
3. NASA-SP-290, Axial Flow turbines, 2002 (re- release), NTIS, USA.
4. NASA-SP-36, Axial Flow Compressors and Fans, NTIS, USA.
5. J H Horlock, Axial flow compressors, Butterworths, 1958, UK.
6. J H Horlock, Axial Flow Turbines, Butterworths, 1965, UK.
7. B Lakshminarayana; Fluid Mechanics and Heat Transfer in turbomachinery, 1995, USA.
8. Dixon, S.L., Fluid Mechanics and Thermodynamics of Turbomachinery, 1998, Elsevier.
9. Cohen, Rogers and Saravanamuttoo, Gas Turbine Theory, Prentice Hall, 2005.

24-508-0109: INTRODUCTION TO AIRCRAFT DESIGN

Course Outcomes:

On completion of this course the student will be able to:

CO1. *Understand the purpose and scope of aircraft design*
CO2. *Apply the stages in aircraft design with emphasis on manufacturability*
CO3. *Develop procedures for evaluation of component weights*
CO4. *Select suitable aerofoil sections and determine the main wing and tail surface areas*
CO5. *Select powerplant and finalise its location along with suitable landing gear loads*
CO6. *Explore stability aspects on the design of control surface.*

Course Articulation Matrix

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	2	1	1
CO2	3	2	3	2	1	1
CO3	3	2	3	2	1	1
CO4	3	2	3	2	1	1

CO5	3	2	3	2	1	1
CO6	3	2	3	2	1	1

1: Low 2: Moderate 3. Highly related

Module I

Introduction - State of art in airplane design, Purpose and scope of airplane design, Classification of airplanes based on purpose and configuration. Factors affecting configuration, Merits of different plane layouts. Stages in Airplane design. Designing for manufacturability, Maintenance, Operational costs, Interactive designs.

Module II

Preliminary design procedure - Data collection and 3-view drawings & their purpose, weight estimation, Weight equation method – Development & procedures for evaluation of component weights. Weight fractions for various segments of mission. Choice of wind loading and thrust loading.

Module III

Design of wing, fuselage and empennage - Selection of aerofoil. Selection of Wing parameters, selection of sweep, Effect of Aspect ratio, Wing Design and Airworthiness requirements, V-n diagram, loads, Structural features. Elements of fuselage design, Loads on fuselage, Fuselage Design. Fuselage and tail sizing. Determination of tail surface areas, Tail design, Structural features, Nose wheel lift off.

Module IV

Power plant selection - Choices available, comparative merits, Location of power plants, Functions dictating the locations.

Design of landing gear and control surface - Landing Gear Design, Loads on landing gear, Preliminary landing gear design. Elements of Computer Aided and Design, Special consideration in configuration lay-out, Performance estimation. Stability aspects on the design of control surface.

References

1. Megson, T. H. G. Aircraft structure for engineering students, 7^{th} edition, Elsevier, 2021.
2. Jan Roskam, Airplane Design, DAR Corporation, Lawrence, Kansas, USA, 2000.
3. Raymer, D.P. Aircraft conceptual Design, AIAA series, 5th edition, 2012.
4. Torenbeck, E. Synthesis of Subsonic Airplane Design, Delft University Press, U.K. 1986.
5. Kuechemann, D, The Aerodynamic Design of Aircraft, American Institute of Aeronautics Publishers, 2012.

24-508-0110: SPACE FLIGHT DYNAMICS

Course Outcomes:

On completion of this course the student will be able to:

CO1. *Understand the basic concepts of solar system and earth's atmosphere*

CO2. *Understand peculiarities of space environment and manned space missions*

CO3. *Analyse Keplerian laws and orbital mechanics*

CO4. *Analyse n-body problem in predicting the motion of a group of celestial objects*

CO5. *Analyse the general aspects of satellite injection into proper orbits*

CO6. *Explore interplanetary trajectories and launching of spacecrafts*

Course Articulation Matrix

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	2	1	1
CO2	3	2	3	2	1	1
CO3	3	2	3	2	1	1
CO4	3	2	3	2	1	1
CO5	3	2	3	2	1	1
CO6	3	2	3	2	1	1

1: Low 2: Moderate 3. Highly related

Module I

Basic concepts - The solar system, Reference frame and coordinate, the celestial sphere, the ecliptic, sidereal time, solar time, standard time, the earth atmosphere.

Space environment - Peculiarities of space environment and its description, effect of space environment on materials of spacecraft structure and astronauts, manned space missions, effect on satellite lifetime.

Module II

Orbital mechanics - The two-body problem, Kepler's laws, Keplerian elements, Keplerian orbits, the N-body problem, orbital and escape velocities, elliptical orbits, geo synchronous orbits, planetary equations of motion.

The general n-body problem - The many-body problem, circular restricted three body problem, liberation points, two body problem, satellite orbits, relation between position and time, orbital element.

Module III

Satellite injection - General Aspects of satellite Injections, Satellite Orbit Transfer, Various Cases, Orbit Deviations Due to Injection Errors.

Satellite orbit perturbations - Special and General Perturbations, Cowell's Method, Encke's Method, Method of vibrations of Orbital Elements, General Perturbations Approach.

Module IV

Interplanetary trajectories - Two dimensional interplanetary trajectories, Fast interplanetary trajectories, three dimensional interplanetary trajectories, Launch of Interplanetary spacecraft, Trajectory about the target planet.

Rocket performance - The boost phase, the ballistic phase, trajectory geometry, optimal flights, time of flight, re-entry phase, the position of the impact point, influence coefficients.

References

1. Cornelisse, J.W., Rocket Propulsion and Space Dynamics, W.H. Freeman & Co., 1984.
2. Thomson, Introduction to Space Dynamics, Dover Publications,Revised edition, 2012.
3. Van de Kamp, P., "Elements of Astromechanics", Pitman, 1979.
4. Willian E. Wiesel, Space Flight Dynamics, Create Space Independent Publishing Platform, 3rd Edition, 2010, ISBN-13: 978-1452879598.
5. George P. Sutton and Oscar Biblarz, Rocket Propulsion Elements, Wiley India Pvt Ltd,7th edition, 2010, ISBN-13: 978-8126525775.

24-508-0111: ADVANCED THERMODYNAMICS

Course Outcomes:

On completion of this course the student will be able to:

CO1. *Understand the fundamentals of availability, irreversibility and second law efficiency for a system*

CO2. *Apply the generalized equation for determining the changes in entropy, enthalpy and internal energy of systems*

CO3. *Analyse the fundamental property relations for systems of variable composition*

CO4. *Model equilibrium in multiphase systems*

CO5. *Apply first and second law analysis of reacting systems*

CO6. *Explore degeneracy of energy levels*

Course Articulation Matrix

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	2	1	1
CO2	3	2	3	2	1	1
CO3	3	2	3	2	1	1
CO4	3	2	3	2	1	1
CO5	3	2	3	2	1	1
CO6	3	2	3	2	1	1

1: Low 2: Moderate 3. Highly related

Module I

Availability, Irreversibility and second law efficiency for a closed system, Control volume, Availability analysis of simple cycles, Thermodynamic potentials, Maxwell relations, Generalised relation for changes in entropy, Internal energy and enthalpy, Generalised relations for *Cp* and *Cv*, Clausius-Claypeyron equation, Joule-Thomson coefficient, Bridgman tables for thermodynamic relations.

Module II

Different equations of state, Fugacity, Compressibility, Principle of corresponding states, Use of generalized charts for enthalpy and entropy departure, Fugacity coefficient, Lee-Kesler generalized three parameter tables, Fundamental property relations for systems of variable composition, Partial molar prosperities, Real gas mixtures, Ideal solution of real gases and liquids, Equilibrium in multi phase systems, Gibbs phase rule for non-reactive components.

Module III

Thermo chemistry, First law analysis of reacting systems, Adiabatic flame temperature, Entropy change of reacting systems, Second law analysis of reacting systems, Criterion for reaction equilibrium composition, Conjugate fluxes and forces, Entropy production, Onsager's reciprocity relations, Thermo-electric phenomena and formulations, Thermodynamics of high gas flow.

Module IV

Microstates and macro-states, Thermodynamic probability, Degeneracy of energy levels, Maxwell-Boltzman, Fermi-Dirac and Bose-Einstein statistics, Microscopic interpretation of heat and work, Evaluation of entropy, Partition function, Calculation of the microscopic properties from partition functions, Collision theory and transport properties.

References

1. Wan Wylen, Gordon J and Sonntag, Fundamental of Classical thermodynamics, John Wiley International, 1994.
2. Yunus A Cengel, Introduction to Thermodynamics and Heat Transfer, McGraw Hill, 1996.
3. Robert Balmer, Thermodynamics, Jaico Publication, 1998.
4. Russell and Adebiyi, Classical Thermodynamics, Saunders College Publication, 1993.
5. Rayner Joel, Basic Engineering Thermodynamics, Addison Wesley, 1996.
6. Bejan Adrian, Advanced Engineering Thermodynamics, John Wiley & Sons, 1998.

24-508-0112: RESEARCH METHODOLOGY & IPR

Course Outcomes:

On completion of this course the student will be able to:

CO1. *Demonstrate knowledge of research processes (reading, evaluating, and developing)*

CO2. *Perform literature reviews using print and online databases*

CO3. *Summarize and discuss important issues and trends within the actual research area.*

CO4. *Write a scientific article within a limited topic but with a quality such that the article could be accepted for presentation in a conference or workshop*

CO5. *Create a scientifically sound and reasonable and well documented plan for a Mastersthesis project of excellent quality.*

CO6. *Compare and contrast the different forms of intellectual property protection in terms of their key differences and similarities.*

Course Articulation Matrix

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	2	3	3	3
CO2	3	3	2	3	2	3
CO3	3	3	2	3	3	3
CO4	3	3	2	3	3	3
CO5	3	3	2	3	3	3
CO6	3	3	2	3	3	3
CO7	3	3	2	3	2	3

1: Low 2: Moderate 3. Highly related

Module I

Meaning of research problem, Sources of research problem, Criteria and Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches to investigation of solutions for research problem - data collection, analysis, interpretation. Necessary instrumentation.

Module II

Effective literature review approaches, Plagiarism, Research ethics. Effective technical writing. How to write a good report and a paper? Developing a Research Proposal, Format of research proposal, Presentation and assessment by a review committee.

Module III

Intellectual Property – Property theories – History of IPR – Nature – Justification – Types – International Conventions and Treaties – International Organisations – Objects and Functions of WIPO, WTO - TRIPS. Patents – Procedure – Provisional and Complete Specifications – Publication – Opposition – Examination – Grant – Term – Rights – Patent of addition – Limitations – Transfer – Compulsory licensing – Infringement – Remedies – Agents.

Module IV

Copyright – Where subsists – Rights conferred – Term of CR – Performer's rights – Assignment and Licensing – Compulsory licensing – Infringement and remedies – Moral rights – International CR – CR Office, Board, Societies. Trademarks – Essentials of good trademarks – Registration – Term – Collective marks – Certification trademarks – Assignment and Transfer – Infringement and Remedies – Appellate Board – Passing off. Semiconductor Integrated Circuit Layout Designs – Registration – Infringement – Appellate Board. Designs – Author and Proprietor – Registration of design – Grounds for refusal of registration – Term of copyright in registered designs – Piracy – Remedies. Geographical Indication of goods. Traditional knowledge: Indigenous, medicinal and bioprospecting knowledge – Need for protection.

References

1. Stuart Melville and Wayne Goddard, Research Methodology: An introduction for Science & Engineering students, Juta& Co Ltd, 1996.
2. Ranjit Kumar, Research Methodology: A Step by Step Guide for beginners, 2nd Edition, Pearson, 2005.
3. Gopalakrishnan N S, and Agitha T G, Principles of Intellectual Property, 2nd Edition, Eastern Book Company, 2015.
4. Bansal K and Bansal P, Fundamentals of Intellectual Property for Engineers, BS Publications, 2013.
5. Deborah E. Bouchoux, Intellectual Property: The Law of Trademarks, Copyrights, Patents, and Trade Secrets, 4th Edition, Cengage Learning, 2012.
6. Markel, Mike, Technical Communication. 11th Edition, Mac Millan, 2015.

24-508-0113: PROPULSION LABORATORY

Course Outcomes:

On completion of this course the student will be able to:

CO1. *Acquire hands on experience on the various test-rigs, experimental set-up*

CO2. *Measure the various technical parameters by instrument and by mathematical relationship*

CO3. *Identify the effect of various parameters on the system and able to correlate them*

CO4. *Develop the report from the experimental procedure and outcome of the experiments*

Course Articulation Matrix

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	3	3	2	2	2
CO2	2	3	3	2	2	2
CO3	2	3	3	2	2	2
CO4	2	3	3	2	2	2

1: Low 2: Moderate 3. Highly related

Syllabus Contents:

1. Study of forced convective heat transfer over a flat plate.
2. Study of free convective heat transfer over a flat plate.
3. Determination of heat of combustion of aviation fuel.
4. Measurement of burning velocity of a premixed flame.
5. Flame stability of pre-mixed flame through flame stability setup.
6. Study of free jet/wall jet.
7. Investigation of back pressure variation in a Convergent and Convergent-Divergent nozzles for perfectly expanding, under expanding and over expanding conditions
8. Preparation of a solid propellant.
9. Computation of burning rate of the propellant.
10. Determine the calorific value of liquid fuel.
11. Measurement of ignition delay of a single propellant with different shapes.
12. Determine the specific impulse of solid motor.
13. Performance study of hybrid motor using a thrust stand.
14. Analysis of grain stress and strain of a solid propellant.
15. Performance and emission measurements in 2 & 4 stroke S.I. engines.
16. Performance and emission measurements in Diesel engines.
17. Performance studies on Centrifugal fans and Axial flow fans.
18. Flow visualization using Schlieren, Shadowgraph, PIV & PLIF.
19. Evaluation of the Calorific value of gaseous and liquid fuels.
20. Burning velocity measurements in laminar flames.

24-508-0114: SEMINAR I

Course Outcomes:

On completion of this course the student will be able to:

CO1. *Improve communicative skills*
CO2. *Overcome performance anxiety in front of an audience*
CO3. *Widen the knowledge of thrust area*
CO4. *Develop the skill for preparing presentation material*
CO5. *Improve self confidence*

Course Articulation Matrix

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	3	3	1	2	2
CO2	2	3	3	1	2	2
CO3	2	3	3	1	2	2

CO4	2	3	3	1	2	2
CO5	2	3	3	1	2	2

1: Low 2: Moderate 3. Highly related

Guidelines:

Students shall individually prepare and submit a seminar report on a topic of current relevance related to the field of mechanical/aerospace engineering. The reference shall include standard journals, conference proceedings, reputed text books and technical reports. The references shall be incorporated in the report reflecting the state-of-the-art in the topic selected. Each student shall present a seminar for about 30 minutes duration on the selected topic. The report and presentation shall be evaluated by a team of internal examiners comprising of two teachers based on style of presentation, technical content, adequacy of references, depth of knowledge and overall quality of the seminar report.

References

1. David F. Griffiths, Desmond J. Higham, Learning LaTeX, Society for Industrial and Applied Mathematics, 2016.
2. Lalit Mali, Libre office 5.1 Impress, Draw, Base book, Vol. 2, Notion Press, 2017.

SEMESTER – II

24-508-0201: AIR BREATHING PROPULSION

Course Outcomes:

On completion of this course the student will be able to:

CO1. *Understand the fundamentals of the governing equations related to jet propulsion*
CO2. *Classify the different forms of jet engines and summarise their working principle*
CO3. *Analyse the engine cycle by considering the efficiencies of each component*
CO4. *Analyse flow through intakes, nozzles and combustion chambers*
CO5. *Evaluate the work done and pressure rise across jet engine compressors*
CO6. *Explore the working of jet engine turbines and significance of blade cooling*

Course Articulation Matrix

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	2	1	1
CO2	3	2	3	2	1	1
CO3	3	2	3	2	1	1
CO4	3	2	3	2	1	1
CO5	3	2	3	2	1	1
CO6	3	2	3	2	1	1

1: Low 2: Moderate 3. Highly related

Module I

Principles of air breathing engines - Operating principles of piston engines – thermal efficiency calculations – illustration of working of gas turbine engines – Thermodynamic processes, Reaction principle, Features of propulsive devices, Momentum theory applied to propulsive devices, Types of propulsive devices, Principle of working of Turbojet, Turboshaft and Scramjet engines - Thrust augmentation techniques, Noise suppression techniques, Comparative study of performance characteristics.

Module II

Thrust equation, Analysis of Turbo jet engine cycle, Component efficiencies, Diffuser efficiency, Compressor efficiency, Burner efficiency, Turbine efficiency, Nozzle efficiency, Analysis of Turboprop, Turbofan and Ramjet engine cycles, Calculation of thrust, thrust power, propulsive efficiency, thermal efficiency, transmission efficiency and overall efficiency.

Module III

Jet engine intakes and exhaust nozzles - Ram effect, Internal flow and stall in subsonic inlets – relation between minimum area ratio and external deceleration ratio – diffuser performance – modes of operation - supersonic inlets – starting problem on supersonic inlets – shock swallowing by area variation – real flow through nozzles and nozzle efficiency – losses in nozzles – thrust reversal.

Jet engine combustion chambers - Combustion equations, Combustion process, classification of combustion chambers – combustion chamber performance – effect of operating variables on performance – flame stabilization, Cooling process, Materials, Aircraft fuels, HHV, LHV, Orsat apparatus.

Module IV

Jet engine compressors - Euler's turbo machinery equation, Principle of operation of centrifugal compressor, Principle of operation of axial flow compressor– Work done and pressure rise – performance parameters axial flow compressors – stage efficiency.

Jet engine turbines - Principle of operation of axial flow turbines– limitations of radial flow turbines- Work done and pressure rise – performance parameters of axial flow turbine – turbine blade cooling methods – stage efficiency calculations – basic blade profile design considerations – matching of compressor and turbine - factors limiting turbine design, materials for turbine blades.

References

1. Hill, P.G. & Peterson, C.R. Mechanics & Thermodynamics of Propulsion, Pearson education (2009).
2. Cohen, H. Rogers, G.F.C. and Saravanamuttoo, H.I.H. Gas Turbine Theory, Pearson Education, Canada, 6th edition, 2008.
3. Mathur, M.L. and Sharma, R.P., Gas Turbine, Jet and Rocket Propulsion, Standard Publishers and Distributors, Delhi, 2nd edition, 2014.
4. Oates, G.C., Aero thermodynamics of Aircraft Engine Components, AIAA Education Series, New York, 1985.
5. Rolls Royce Jet Engine, Rolls Royce; 4th revised edition, 1986.

24-508-0202: ROCKET PROPULSION

Course Outcomes:

On completion of this course the student will be able to:

CO1. *Understand the fundamentals of rocket propulsion*
CO2. *Classify the different types of rockets and summarise their working principle*
CO3. *Analyse the rocket performance characteristics using rocket equation*
CO4. *Explain the working of solid and liquid propellant rocket engines*
CO5. *Compare solid and liquid propellants and their properties*
CO6. *Explore the methods employed for the cooling of thrust chambers in rockets*

Course Articulation Matrix

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	2	1	1
CO2	3	2	3	2	1	1
CO3	3	2	3	2	1	1
CO4	3	2	3	2	1	1
CO5	3	2	3	2	1	1
CO6	3	2	3	2	1	1

1: Low 2: Moderate 3. Highly related

Module I

Introduction to rocket propulsion: Classification and applications of rockets – Reaction principle – Thrust equation – Classification of rockets based on propellants used – solid, liquid and hybrid – Comparison of these engines with special reference to rocket performance – electric propulsion – classification - electro thermal – electro static – electromagnetic thrusters - geometries of Ion thrusters- beam/plume characteristics – hall thrusters.

Fundamentals and Definitions – Thrust, Exhaust Velocity, Energy and efficiencies, multiple propulsion systems, typical performance values, variable thrust and simple problems, Effective jet velocity, Specific Propellant Consumption, Impulse to weight ratio, Thrust coefficient, Weight flow coefficient, Mass ratio, Propellant mass fraction, Characteristic velocity.

Module II

Rocket equation: Burn out velocity, Specific Impulse, Altitude gain during powered and coasting flights, Comparison of Air Breathing and Rocket Propulsion Systems, Classification of Rockets, Nozzle Expansion, Real Nozzles, Ideal rocket propulsion systems, isentropic flow through nozzles, nozzle configuration, real nozzles, nozzle alignment, over expanded, under expanded nozzles and optimum expansion in nozzles.

Thrust Chambers: Injectors, flow characteristics, factors influencing injection behavior, heat transfer analysis, starting and ignition, life of thrust chambers, random variable thrust, sample thrust chamber design analysis, Thrust Vector Control with single nozzle and multiple nozzles, Integration with vehicle, Combustion Instability, Cooling of Thrust Chambers – Radiation cooling, Ablative cooling, Regenerative cooling, Film cooling, Transpiration cooling.

Module III

Liquid Propellants: Propellant properties, liquid oxidizers, liquid fuels, liquid monopropellants, gaseous propellant, safety and environment concern, Combustion process.

Liquid Propellant Rocket Engine: Types of propellants, propellant tanks, propellant feed systems, gas pressure feed systems, tank pressurization, turbopump feed system, rocket engines for manoeuvring and orbit adjustments, Injectors, Combustion Mechanisms, Combustion Instability.

Module IV

Solid Propellants: Classification, propellant characteristics, hazards, propellant ingredients, other propellant categories.

Solid Propellant Rocket Motor: Basic relations and propellant burning rate, performance issues, propellant grain and grain configuration, propellant grain stress and strain, propellant area ratio, linear burning rate, altitude control and side manoeuvres with solid propellant rocket motors. Erosive burning, Igniters – Pyrotechnic & Pyrogen Igniters.

Orbital mechanics: Kepler's laws, Orbital velocity, Transfer orbits, Re-entry aerodynamics.

References

1. Sutton G. P. and Ross D. M., Rocket Propulsion Elements, John Wiley Publication, New York, 1991.
2. Zucrow M. J., Aircraft & Missile Propulsion, John Wiley & Sons, New York, 1958.
3. Hill P., and Peterson C., Mechanics and Thermodynamics of Propulsion, Addisson Wesley, 1992.
4. Barrere M., Janmotte A., Venbeke B. F., Vandenkerchove J., Rocket Propulsion, Elsevier Publications Company, London, 1960.
5. James R, Introduction to Rocket Propulsion, Noah Books, Third Edition, 2018.

6. G.C. Oates, Aerothermodynamics of gas turbines and rocket prolusion, AIAA Education Series Third Edition, 1998.
7. 6. H. Cohen, Rogers, G.F.C. and H.I.H. Saravanamuttoo, Gas Turbine Theory, Dorling Kindersley, 5th edition, 2002.

24-508-0203: COMPUTATIONAL FLUID DYNAMICS

Course Outcomes:

On completion of this course the student will be able to:

CO1. *Understand the governing equations and boundary conditions for various thermal engineering problems*
CO2. *Apply numerical methods for various thermal engineering problems.*
CO3. *Model partial differential equations based on explicit, implicit and semi implicit schemes*
CO4. *Analyse criteria for numerical stability and convergence*
CO5. *Solve one and two dimensional heat equations using finite volume method*
CO6. *Explore the application of CFD codes in modelling various thermal engineering problems*

Course Articulation Matrix

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	2	1	1
CO2	3	2	3	2	1	1
CO3	3	2	3	2	1	1
CO4	3	2	3	2	1	1
CO5	3	2	3	2	1	1
CO6	3	2	3	2	1	1

1: Low 2: Moderate 3. Highly related

Module I

Review of fluid dynamic processes in flows, Equations of mass, momentum, energy and species balance, Specification of boundary conditions, Turbulent flow models, Turbulence kinetic energy, Free turbulent flows, Viscous sub layer, Log-law layer, Outer layer.

Module II

Application of Finite Difference Methods, Discretization, Taylor series method, Central differencing, Forward and Backward differencing, Estimation of truncation and discretization errors, Explicit, Implicit and Semi-Implicit Techniques, Crank Nicolson scheme, Criteria for numerical stability, Convergence analysis.

Module III

Flux formulation for Finite Volume Method, Transient one dimensional conduction, Two dimensional steady heat conduction, Convective diffusion, Incorporation of variable properties, Upwinding and artificial diffusion, QUICK and SIMPLE Algorithms, Solution of discretized equation, Tri Diagonal Matrix Algorithm.

Module IV

Modelling of flow problems; Simulation of incompressible and compressible flows; Implementation of Boundary conditions, Inlet and Outlet Boundary conditions, Wall Boundary condition, Symmetry and Periodic Boundary conditions, Fundamentals of grid generation; Structured and unstructured grids, Introduction to the use of commercial as well as open-source software packages; Use of CFD software for solving fluid flow and thermal engineering problems, Case studies.

References

1. Muralidhar K., and Sundarajan T., Computational fluid flow & heat transfer, Narosa Publishing House, 1995.
2. Suhas V. Patankar, Numerical heat transfer and Fluid flow, Hemisphere Publishing Corporation, 1980.
3. Versteeg H. K., and Malalasekera W., An Introduction to Computational Fluid Dynamics, Pearson, 1995.
4. John D Anderson, Computational fluid dynamics, McGraw Hill, 1995.
5. Tu Jiyuan, Yeoh Guan Heng and Liu Chaoqun, Computational Fluid Dynamics: A Practical Approach, Elsevier, 2012.
6. F. Moukalled, L. Mangani, M. Darwish, The Finite Volume Method in Computational Fluid Dynamics - An Advanced Introduction with OpenFOAM® and MATLAB, Springer Publications, 2015.

24-508-0204: HYPERSONIC FLOWS

Course Outcomes:

On completion of this course the student will be able to:

CO1. *Understand the basic concepts of entropy layers*

CO2. *Understand the shock wave and expansion wave relations of inviscid hypersonic flows*

CO3. *Analyse shock expansion methods and calculate surface flow properties*

CO4. *Analyse hypersonic boundary layer theory*

CO5. *Evaluate hypersonic aerodynamic heating and heat flux*

CO6. *Explore role of similarity parameters for viscous interaction in hypersonic flows*

Course Articulation Matrix

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	2	1	1
CO2	3	2	3	2	1	1
CO3	3	2	3	2	1	1
CO4	3	2	3	2	1	1
CO5	3	2	3	2	1	1
CO6	3	2	3	2	1	1

1: Low 2: Moderate 3. Highly related

Module I

Basics of hypersonic aerodynamics: Thin shock layers – entropy layers – low density and high-density flows – hypersonic flight paths -hypersonic flight similarity parameters – shock wave and expansion wave relations of inviscid hypersonic flows.

Module II

Surface Inclination Methods for Hypersonic Inviscid Flows: Local surface inclination methods – modified Newtonian Law – Newtonian theory – tangent wedge or tangent cone and shock expansion methods – Calculation of surface flow properties.

Module III

Viscous hypersonic flow theory: Navier-Stokes equations – boundary layer equations for hypersonic flow – hypersonic boundary layer – hypersonic boundary layer theory and non-similar hypersonic boundary layers – hypersonic aerodynamic heating and entropy layers effects on aerodynamic heating – heat flux estimation.

Module IV

Viscous Interactions in Hypersonic Flows: Strong and weak viscous interactions – hypersonic shockwaves and boundary layer interactions -Estimation of hypersonic boundary layer transition – Role of similarity parameter for laminar viscous interactions in hypersonic viscous flow.

References

1. Heiser, W. H. and Pratt, D. T., Hypersonic Air Breathing Propulsion, AIAA, 1994.
2. John T. Bertin, Hypersonic Aerothermodynamics, AIAA Inc., Washington DC, 1994.
3. John D. Anderson, Hypersonic and High Temperature Gas Dynamics, McGraw Hill, 2002.
4. Wallace D. Hayes and Ronald F. Probstein, Hypersonic Flow Theory, 2nd edition, Academic Press, 1959.

24-508-0205: COMPUTATIONAL HEAT TRANSFER AND FLUID FLOW

Course Outcomes:

On completion of this course the student will be able to:

CO1. *Understand the classification of partial differential equations*
CO2. *Apply Taylor series expansion in finite difference method*
CO3. *Analyse consistency and convergence criteria in explicit and implicit methods*
CO4. *Analyse the stability of 1D and 2D diffusion equations*
CO5. *Evaluate upwind biased difference schemes and its significance*
CO6. *Explore pressure correction and velocity correction equations in FVM*

Course Articulation Matrix

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	2	1	1
CO2	3	2	3	2	1	1

CO3	3	2	3	2	1	1
CO4	3	2	3	2	1	1
CO5	3	2	3	2	1	1
CO6	3	2	3	2	1	1

1: Low 2: Moderate 3. Highly related

Module I

Introduction: Brief introduction of ODE (IVP and BVP) and PDE, Initial and Boundary conditions, classification of PDE, various methods to solve PDE numerically along with their advantages and disadvantages.

FDM: Taylor series expansion, Finite difference equations (FDE) of 1st, and 2nd order derivatives, Truncation errors, order of accuracy.

Application of FDM: Steady and unsteady one- and two-dimensional heat conduction equations, one-dimensional wave equations, General method to construct FDE.

Aspects of FDE: Convergence, consistency, explicit, implicit and C-N methods.

Module II

Solution of simultaneous equations: direct and iterative methods; Jacobi and various Gauss-Seidel methods (PSOR, LSOR and ADI), Gauss-elimination, TDMA (Thomas), Gauss-Jordan, other direct and indirect methods.

Errors and Stability of FDE: Diffusion and dispersion errors Stability of 1D and 2D diffusion equations, 1D wave equation (FTCS, FTBS and FTFS).

Modified equations of FD formulation: Diffusion and dispersion errors of modified equation (wave equation) having second and third order derivatives, modified wave number and modified speed.

Module III

Upwinding: Upwinding of convective terms and its significance, Transportive and conservative properties. Upwind biased difference schemes and its significance.

FDE in other coordinate systems: Cylindrical and polar coordinate systems.

FVM: Two approaches of generating Cartesian grids, Solution of fin problem in FVM, Handling of BCs in FVM; Generalized FVM approach for orthogonal grids (complex geometry).

Stream function-vorticity approach: Derivation of stream function and vorticity equations; derivation pressure Poisson equation. Applications with problems.

Module IV

Primitive variable approach: Grid system (Staggered vs collocated grids); their advantages and disadvantages; control volumes for continuity and N-S equations. MAC method; derivation of pressure correction equations; discretization of GDE and BCs for channel flow; solution algorithm; stability constraints. Projection/Fractional step method; solution algorithm; difference with MAC. SIMPLE and SIMPLER method (FVM): derivation of pressure and pressure-correction and velocity correction equations. Discretization and solution algorithm.

References

1. K. Muralidhar, T. Sundararajan, Computational Fluid Flow and Heat Transfer, Second Edition, (Narosa), 2011.
2. P. S. Ghoshdastidar, Computer Simulation of Flow and Heat Transfer, (4th Edition, Tata McGraw-Hill), 1998.
3. Hirch C., Numerical Computation of Internal and External Flows, Elsevier, 2007.
4. S. V. Patankar, Numerical Heat Transfer and Fluid Flow, (Series in Computational Methods in Mechanics and Thermal Sciences), Hemisphere Publishing Corporation, 1980.
5. Zikanov. O., Essential Computational Fluid Dynamics, Wiley 2010.
6. Chung T. J., Computational Fluid Dynamics, Cambridge University Press, 2003.

24-508-0206: FINITE ELEMENT ANALYSIS

Course Outcomes:
On completion of this course the student will be able to:
CO1. *Understand variational and weighted residual approaches*
CO2. *Construct global stiffness matrix and load vector*
CO3. *Model two dimensional problems using constant strain triangle*
CO4. *Analyse selected problems of stress, vibration and structural stability*
CO5. *Model heat conduction and fluid flow problems*
CO6. *Explore the use of FEM codes in the evaluation of existing designs*

Course Articulation Matrix

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	2	1	1
CO2	3	2	3	2	1	1
CO3	3	2	3	2	1	1
CO4	3	2	3	2	1	1
CO5	3	2	3	2	1	1
CO6	3	2	3	2	1	1

1: Low 2: Moderate 3. Highly related

Module I
Finite element modelling, Variational and weighted residual approaches, Potential energy approach, Galerkins approach, Shape functions, natural co-ordinates system, element and global stiffness matrix, Assembly of global stiffness matrix and Load vector.

Module II
Finite element equations, Treatment of boundary conditions, errors, convergence and patch test, higher order elements, Application to solution of selected problems of stress analysis, dynamics and vibrations, structural stability, Two dimensional problems using constant strain triangles.

Module III
Treatment of material and geometric nonlinearities, contact problems, heat conduction and selected fluid problems, mesh generation, modelling; numerical techniques, errors and convergence.

Module IV

Axi-symmetric formulation, Iso-parametric elements and numerical integration, Use of commercial packages, Finite element evaluation of existing complete designs, Comparison with conventional analysis, model revision.

References

1. Zienkiewicz O. C., Taylor R. L., Zhu J. Z., The Finite Element Method: Its Basis and Fundamentals, Elsevier, 2005.
2. Reddy J. N., Introduction to finite element method, McGraw-Hill Higher Education, 1993.
3. Cook R. D., Concepts & applications of finite element analysis, Wiley, 1976.
4. Chandrupatla and Belegundu, An Introduction to Finite element method in Engineering, Pearson Education, 1996.
5. Chandrupala T, Finite Element Analysis for engineering and technology, Universities Press, 1997.
6. Krishnamoorthy C. S., Finite Element Analysis, Tata Mc Graw Hill, 1994.

24-508-0207: INTRODUCTION TO COMBUSTION

Course Outcomes:

On completion of this course the student will be able to:

CO1. *Understand the thermodynamics of combustion*
CO2. *Apply the equations of species mass, momentum and energy in mass transfer*
CO3. *Model basic reaction kinetics and simplification of reaction mechanism*
CO4. *Analyse laminar premixed combustion*
CO5. *Evaluate turbulent premixed combustion and flame stabilization*
CO6. *Explore the diagnostics of combustion, chemical species, particle and spray diagnostics*

Course Articulation Matrix

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	2	1	1
CO2	3	2	3	2	1	1
CO3	3	2	3	2	1	1
CO4	3	2	3	2	1	1
CO5	3	2	3	2	1	1
CO6	3	2	3	2	1	1

1: Low 2: Moderate 3. Highly related

Module I

Introductory concepts, Review of thermodynamics, Thermodynamics of combustion, Stoichiometry of combustion, heats of reaction and formation, Mass transfer definitions: Fick's law, Equations of conservation of species mass, momentum, and energy; multi-component diffusion equation adiabatic flame temperature.

Module II

Chemistry of Combustion: Basic Reaction Kinetics, Elementary reactions, Chain reactions, Multistep reactions, simplification of reaction mechanism, Global kinetics.

Physics of Combustion: Fundamental laws of transport phenomena, Conservations Equations, Transport in turbulent flow.

Module III

Laminar Premixed combustion, non-premixed (diffusion) combustion, partially premixed combustion. Turbulent premixed combustion, non-premixed (diffusion) combustion, partially premixed combustion. Droplet and spray combustion, Flame stabilization.

Module IV

Combustion Measurements, Flow field diagnostics, Temperature diagnostics, Chemical species diagnostics, Particle and spray diagnostics.

References

1. Stephen R Turns, An Introduction to Combustion, Mc-Graw Hill, 2nd edition, 2006.
2. Mukunda H. S., Understanding Combustion, University Press, 2nd Edition 2009.
3. Kanury A Murty, Introduction to Combustion Phenomena, Gordon and Breach, 1975.
4. Kenneth K Kuo, Principles of Combustion, John Wiley and Sons, 1986.
5. Forman A Williams, Combustion Theory: The Fundamentals, Benjamin and Cummings publishing, 2nd edition, 1985.
6. Irvin Glassman and R. A. Yetter, Combustion, Academic press, 4th edition, 2008.
7. Roger A Strehlow, Combustion Fundamentals, Mc-Graw Hill, 1984.
8. LawC. K., Combustion Physics, Cambridge University Press, 2006.
9. Kohse-hoinghaus Katharina, Applied combustion diagnostics, Taylor& Francis, 2002.
10. Eckbreth A.C, Laser diagnostics for combustion temperature & species, Gordon Breach publishers, 1996.
11. Raffel M., Willert, C.E., Wereley S. T., Kompenhans, J, Particle Image Velocimetry, A Practical Guide, Springer, 2007.

24-508-0208: PRINCIPLES OF TURBO MACHINERY

Course Outcomes:

On completion of this course the student will be able to:

CO1. *Understand transfer of energy in turbo machinery and performance characteristics*
CO2. *Apply Euler's equation of turbo machinery and extend it to multi stage turbo machines*
CO3. *Explain the working of centrifugal fans and fan stage parameters*
CO4. *Develop design parameters for blade angle and blade shape*
CO5. *Analyse the performance of turbo machinery*
CO6. *Explore cascade theory on blade efficiency*

Course Articulation Matrix

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	2	1	1
CO2	3	2	3	2	1	1

CO3	3	2	3	2	1	1
CO4	3	2	3	2	1	1
CO5	3	2	3	2	1	1
CO6	3	2	3	2	1	1

1: Low 2: Moderate 3. Highly related

Module I

Classification of turbo machines, Energy transfer in turbo machines, Losses and efficiencies, Performance characteristics, Specific work, Representation of specific work in T-S and h-S diagrams, Internal and external losses, Relationship between fluid mechanics and thermodynamics of turbo-machinery process.

Module II

Euler's equation of turbo machinery, Ideal and actual velocity triangles, Slip and its estimation, General velocity triangle for a rotor, Multi stage turbo machines, Axial flow fans, Construction and operation, types of stages, performance of fans, Applications, Centrifugal fans, Construction and operation, fan stage parameters.

Module III

Impulse and reaction type machines, Degree of reaction, Effect of outlets blade angle on blade shape, Blade design parameters: Flow and loading coefficients, Degree of reaction, blade cascades and nomenclature – lift and drag coefficients, Elementary concept of three dimensional flow, Free and forced vortex.

Module IV

Model laws, specific speed and shape number, Special features of hydro, steam and gas turbines, performance characteristics of turbo machines, Cavitation, Surge and Stall, Thin aerofoil theory, Cascade mechanics.

References

1. Shepherd, D. G., Principles of Turbomachinery, Macmillan Co., New York, 1957.
2. Csanady, G. T., Theory of Turbomachines, McGraw Hill, New York, 1964.
3. Dixon, S. L., Fluid Mechanics, Thermodynamics of Turbomachinery, 3rd Ed., Pergamon Press, Oxford, 1978.
4. Yahya, S. M., Turbines, Compressors and Fans, Tata McGraw Hill, New Delhi, 1983.
5. Lazarkiewicz, S. and Trosklanski, Impeller Pumps, Pergamon Press, Oxford, 1965.
6. Nechleba, M., Hydraulic Turbine, Artia Publishers, Prague, 1957.

24-508-0209: AEROACOUSTICS

Course Outcomes:

On completion of this course the student will be able to:

CO1. *Understand the challenges in computational aeroacoustics*

CO2. *Understand the types of acoustic sources*

CO3. *Analyse plane and spherical wave solutions with suitable examples*
CO4. *Apply Lighthill's analogy to obtain far field acoustic solution*
CO5. *Compare Ffowcs Williams Hawkings method with Kirchhoff's method*
CO6. *Explore the significance of RANS and LES in determining acoustic nonlinearities*

Course Articulation Matrix

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	2	1	1
CO2	3	2	3	2	1	1
CO3	3	2	3	2	1	1
CO4	3	2	3	2	1	1
CO5	3	2	3	2	1	1
CO6	3	2	3	2	1	1

1: Low 2: Moderate 3. Highly related

Module I

Introduction: Historical perspectives; challenges in computational aero acoustics (CAA); basics on sound waves. Conservation equations, wave equation. Acoustic energy, intensity, Fourier analysis, power spectrum. Acoustic sources: pulsating sphere; point sources, free-space Green's functions; monopoles, dipoles and quadrupoles; Green's function solutions for 1-D, 2-D and 3-D wave equations.

Module II

Classical Acoustics: Linearized equations of motion; Kovasznay's decomposition; classical wave equation, plane wave solution of wave equation; examples of plane wave propagation, spherical wave solution; causality; compactness; acoustics in Fourier space, propagation in inhomogeneous media: discontinuity in impedances and velocities. General solutions for medium at rest: distributed source, point force, point stress; moving point sources, Kirchhoff--Helmholtz theorem for rigid boundaries; radiation from baffled pistons, near-wall sources; extensions for moving boundaries.

Module III

Sound Sources: Lighthill's analogy; interpretation; analysis of Lighthill source; moving source version, integral solution of Lighthill's equation; far-field approximation; acoustically compact and non-compact sources; Lilley/Lilley--Goldstein equations; Goldstein's generalized analogy; effect of solid surfaces: Curle's equation; sound produced by turbulence near rigid boundary; Powell's image theorem; generalized function theory; Ffowcs Williams--Hawkings equation; comparison with Kirchhoff method.

Module IV

Computational Aero Acoustics: Challenges and simplifications; spatial and temporal discretizations; boundary conditions, hybrid methods: numerical evaluation of Lighthill's integral; direct methods: direct simulations; methods based on coherent structures; applications of RANS and LES. Sound waves at a discontinuity, ray theory, resonators, acoustic nonlinearities.

References

1. Goldstein, M. E., Aeroacoustics, McGraw-Hill, 1976.
2. Crighton, D. G., Basic principles of aerodynamic noise generation, Prog. Aerospace Sci., 16(1), 1975 pp. 31-96.
3. Howe, M. S., Theory of vortex sound, Cambridge, 2003.
4. Pierce, A. D., Acoustics, Acoustical Society of America, 1989.
5. Crighton, D. G., Dowling, A. P., Ffowcs Williams, J. E., Heckl, M. and Leppington, F. G., Modern methods in analytical acoustics, Springer, 1992.

24-508-0210: ADVANCED HEAT TRANSFER

Course Outcomes:

On completion of this course the student will be able to:

CO1. *Understand the fundamentals of both steady and unsteady heat transfers and heat transfer through extended surfaces*
CO2. *Apply finite difference method and solve 1D and 2D conduction equations*
CO3. *Analyse steady laminar and turbulent heat transfer in external and internal flows*
CO4. *Model laminar and turbulent forced convection in ducts and plates*
CO5. *Evaluate heat transfer with phase change*
CO6. *Explore radiation characteristics of particle systems*

Course Articulation Matrix

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	2	1	1
CO2	3	2	3	2	1	1
CO3	3	2	3	2	1	1
CO4	3	2	3	2	1	1
CO5	3	2	3	2	1	1
CO6	3	2	3	2	1	1

1: Low 2: Moderate 3. Highly related

Module I

Review of Heat Transfer fundamentals, Transient conduction, Use of Heisler and Grober chart, General lumped capacitance analysis, Extended surface Heat Transfer, Overall surface efficiency, Steady state analysis and optimization. Introduction to finite difference method to solve conduction equations. 1-D, 2-D conduction, Unsteady conduction solutions.

Module II

Thermal boundary layers, Momentum and energy equations, Integral method to solve heat transfer from flat plate laminar case. Steady Laminar and Turbulent Heat Transfer in External and Internal Flows, Heat Transfer at high speeds.

Module III

Laminar and Turbulent Forced Convection in Ducts and Plates, Forced convection over cylinders, spheres and bank of tubes, Two Phase Flow correlations, Heat transfer with phase change, Condensation and boiling heat transfer, Heat transfer in condensation, Effect of non-condensable gases in condensing equipment, Flow boiling correlations.

Module IV

Radiation basics, Gas Radiation, Radiative exchange in furnaces, Radiation network, Radiation characteristics of particle systems, Thermal radiation of a luminous fuel oil and gas, Diffusion and Convective Mass Transfer.

References

1. Frank P. Incropera and David P. Dewitt, Fundamentals of Heat and Mass Transfer, John Wiley and Sons, 1981.
2. R. Byron Bird, Warren E. Stewart and Edwin N. Lightfoot, Transport Phenomena, John Wiley & Sons, 1994.
3. W. M. Kays and M. E. Crawford, Convective Heat and Mass Transfer, McGraw Hill Inc., 1993.
4. Frank Kreith and Mark S. Bohn, Principles of Heat Transfer, Harper and Row Publishers, 1986.

24-508-0211: CONVECTION AND TWO PHASE FLOWS

Course Outcomes:

On completion of this course the student will be able to:

CO1. *Understand the fundamentals conservations laws in fluid dynamics*
CO2. *Derive different non-dimensional numbers*
CO3. *Analyse convection boundary layer and origin of plumes*
CO4. *Explain boiling and condensation*
CO5. *Construct two phase flow patterns and flow pattern maps*
CO6. *Explore the instability of vapour layers and jets*

Course Articulation Matrix

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	2	1	1
CO2	3	2	3	2	1	1
CO3	3	2	3	2	1	1
CO4	3	2	3	2	1	1
CO5	3	2	3	2	1	1
CO6	3	2	3	2	1	1

1: Low 2: Moderate 3. Highly related

Module I

Conservation laws, Navier Stokes equations, Differential and Integral forms; External laminar flows, Flat plate, Wedge flows, flow over cylinders, Separation, Internal Laminar Flow, Circular pipe, Free convection; Vertical plate cylinders, mixed convection, Physical mechanism of convection, Nusselt number, Schimidt number, Rayleigh number, Prandtl number, Peclet number, Grashof number.

Module II

Laminar natural convection boundary layer, Rayleigh-Benard convection, convection through membrane and its formulation, thermal and concentration boundary layer, different regimes of convection and plume structure, concentration profile, the origin of plumes rising from a heated surface and membrane, boundary layer flow along a vertical wall, inclined walls and horizontal walls.

Module III

Boiling and condensation, Boiling heat transfer, pool boiling, boiling regimes and the boiling curve, heat transfer correlation in pool boiling, flow boiling, condensation heat transfer, film condensation, heat transfer correlations for film condensation, vertical plates, inclined plate, vertical tube, horizontal tubes and spheres, horizontal tube banks, drop-wise condensation.

Module IV

Two-phase flow patterns and flow pattern maps, Homogeneous flow, pressure gradient in homogeneous flow, Two-phase multipliers, Pressure drop in two-phase flow-overall methods for separated flow, pressure gradient in separated flow, Methods of measuring the momentum flux, frictional pressure gradient, flooding in two-phase flow, critical heat flux in pool boiling, instability of the vapour layer, instability of vapour jets.

References

1. Kays W. M., and Crawford M. E., Convective Heat and Mass Transfer, McGraw Hill Inc., 1993.
2. Frank Kreith and Mark S. Bohn, Principles of Heat Transfer, Harper and Row Publishers, 1986.
3. Massoud Kaviany, Principles of convective heat transfer, Springer, 2001.
4. Collier J. G., and Thome J. R., Convective boiling and condensation, Oxford University Press, 1996.
5. Whalley P. B., Two-phase flow and heat transfer, Oxford University press, 1996.

24-508-0212: AEROSPACE MATERIALS

Course Outcomes:

On completion of this course the student will be able to:

CO1. *Understand the components of aerospace systems and their performance requirements.*

CO2. *Explain fundamentals of materials science and engineering as applicable to aerospace components including crystalline structures, defects, mechanical properties, failure modes etc.*

CO3. *Identify desired properties and applications of various aerospace materials including aluminium, titanium and nickel alloys, stainless steels, superalloys, polymer composites and ceramic composites.*

CO4. *Select appropriate aerospace materials for different structural components, propulsion systems and thermal protection systems based on operating conditions such as load, temperature, corrosion/oxidation environment etc.*
CO5. *Analyze defects, failure modes and performance limits in metallic and composite aerospace materials.*
CO6. *Evaluate the suitability of new and advanced aerospace materials for next-generation applications through analysis and testing.*

Course Articulation Matrix

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	2	1	1
CO2	3	2	3	2	1	1
CO3	3	2	3	2	1	1
CO4	3	2	3	2	1	1
CO5	3	2	3	2	1	1
CO6	3	2	3	2	1	1

1: Low 2: Moderate 3. Highly related

Module I
Introduction - Overview of aerospace systems and components such as airframes, gas turbine engines, rocket motors etc. Special performance requirements - strength, stiffness, fracture toughness, creep and fatigue resistance, thermal stability, corrosion/oxidation resistance etc. Classification of aerospace materials. Recent trends and future outlook.

Module II
Metals - Crystal structures and microstructures. Strengthening mechanisms. Aluminium alloys - 2xxx, 6xxx, 7xxx series - properties, processing, applications. Titanium alloys, stainless steels, nickel base superalloys for elevated temperature use - microstructures, strengthening mechanisms, fabrication, applications and limits.

Module III
Polymers and Composites - Properties and processing of thermosets and thermoplastics. Environmental degradation and flammability. Manufacturing techniques for fiber-reinforced composites. Polymer matrix composites, metal matrix composites and ceramic matrix composites - properties, applications and issues.

Module IV
Ceramics - Crystal structures of ceramics. Mechanical and thermal properties of technical ceramics - oxides, carbides, nitrides and borides. Fracture, fatigue and creep in ceramics. Ceramic coatings and reinforcement. Testing and evaluation of monolithic ceramics and ceramic composites.

References
1. M. Peters et al., Aerospace Materials and Material Technologies, Springer, 2016.

2. Brian Cantor, Grant Mordike, Aerospace Materials, Carl Hanser Verlag GmbH Co KG, 2021.
3. N. Eswara Prasad et al., Aerospace Material Systems, Springer, 2022.
4. R.W. Hertzberg, Deformation and Fracture Mechanics of Engineering Materials, Wiley, 2020.

24-508-0213: COMPUTATIONAL ANALYSIS LABORATORY

Course Outcomes:
On completion of this course, the student will be able to:
CO1. *Develop and effectively employ solid modelling and simulation tools.*
CO2. *Choose right specification, appropriate structural models and create a simple trade diagram.*
CO3. *Make use of tools to analyse stress distribution over complex structural components.*
CO4. *Construct 3D designs and conduct flow analysis.*

Course Articulation Matrix

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	3	3	3	2	1
CO2	2	3	3	3	2	1
CO3	2	3	3	3	2	1
CO4	2	3	3	3	2	1

1: Low 2: Moderate 3. Highly related

Syllabus Contents:
1. Grid independence study and convergence test using any simple case like cylinder.
2. Simulation of flow over an aero foil.
3. Simulation of flow over backward facing step.
4. Simulation of Karman vortex trail (vortex shedding) using circular cylinder.
5. External flow simulation of subsonic and supersonic aero foils.
6. Internal flow simulation of subsonic, sonic and supersonic flow through a CD nozzle.
7. Structural analysis of bar and beam.
8. Structural analysis of truss.
9. Structural analysis of tapered wing.
10. Structural analysis of fuselage structure.
11. Analysis of composite laminate structures.
12. Heat transfer analysis of structures.
13. Simulation of incompressible flow over aerofoils.
14. Simulation of compressible flow over aerospace vehicles.
15. Simulation of aircraft intakes and nozzle flows.

24-508-0214: SEMINAR II

Course Outcomes:
On completion of this course the student will be able to:
CO1. *Improve communicative skills*

CO2. *Overcome performance anxiety in front of an audience*
CO3. *Widen the knowledge of thrust area*
CO4. *Develop the skill for preparing presentation material*
CO5. *Improve self confidence*

Course Articulation Matrix

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	3	3	1	2	2
CO2	2	3	3	1	2	2
CO3	2	3	3	1	2	2
CO4	2	3	3	1	2	2
CO5	2	3	3	1	2	2

1: Low 2: Moderate 3. Highly related

Students shall individually prepare and submit a seminar report on a topic of current relevance related to the proposed project work related to mechanical/aerospace engineering. The reference shall include standard journals, conference proceedings, reputed text books and technical reports. The references shall be incorporated in the report reflecting the state-of-the-art in the topic selected. Each student shall present a seminar for about 30 minutes duration on the selected topic. The report and presentation shall be evaluated by a team of internal examiners comprising of two teachers based on style of presentation, technical content, adequacy of references, depth of knowledge and overall quality of the seminar report.

References

1. David F. Griffiths, Desmond J. Higham, Learning LaTeX, Society for Industrial and Applied Mathematics, 2016.
2. Lalit Mali, Libre office 5.1 Impress, Draw, Base book, Vol. 2, Notion Press, 2017.

SEMESTER- III

24-508-0301: INTERNSHIP/MOOC COURSE/MINI PROJECT

Course Outcomes:

On successful completion of the course, the student will be able to:

CO1. *Gain exposure to professional work culture and practices.*

CO2. *Apply and correlate theory and practice in the area of aerospace engineering.*

CO3. *Develop domain specific problem solving and critical thinking in day to day operation, trouble shooting and minor modifications at site*

CO4. *Create proper documentation of the work and present it before a committee.*

Course Articulation Matrix

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	3	3	2	1	2
CO2	2	3	3	2	1	2
CO3	2	3	3	2	1	2
CO4	2	3	3	2	1	2

1: Low 2: Moderate 3. Highly related

The objective of this internship training is to expose the students to industry/research environment and practices. The students have to undergo training for duration of 4 weeks in any industry/research centres related to mechanical/aerospace engineering after the completion of second semester. The students shall submit a report of the training undergone and present the contents of the report before the evaluation Committee. Evaluation committee will award the marks based on training quality, contents of the report and presentation.

Students can also register for MOOC courses related to mechanical/aerospace engineering or take up small problems in the field of aerospace engineering as mini project. It can be related to solution to an engineering problem, verification and analysis of experimental data available, conducting experiments on various engineering subjects, material characterization, studying a software tool for the solution of an engineering problem etc.

24-508-0302: PROJECT DISSERTATION PHASE - I

Course Outcomes:

On completion of this course the student will be able to:

CO1. *Get exposed to self-learning various topics*

CO2. *Learn to survey the literature such as books, national/international refereed journals and contact resource persons for the selected topic of research*

CO3. *Learn to write technical reports*

CO4. *Develop oral and written communication skills to present and defend their work in front of technically qualified audience*

Course Articulation Matrix

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	3	2	3
CO2	3	3	3	3	2	3
CO3	3	3	3	3	2	3
CO4	3	3	3	3	2	3

1: Low 2: Moderate 3. Highly related

Guidelines:

The Project work will start in the 3rd semester and should preferably be a problem with research potential and should involve scientific research, design, generation/collection and analysis of data, determining solutions and must preferably bring out the individual's contribution. The Project seminar conducted should be based on the area in which the candidate has undertaken the dissertation work. The examination shall consist of the preparation of report consisting of a detailed problem statement and a literature review. The preliminary results (if available) of the problem may also be discussed in the report. The work has to be presented in front of the examiners panel consisting of internal examiner and project guide as set by the Head and PG course coordinator. The candidate has to be in regular contact with his guide and the topic of dissertation must be mutually decided by the guide and student. Each student shall individually carry out a project in an Industry / R&D institution / University department. The project work shall be reviewed and evaluated periodically during the 3rd semester and continued in the 4th semester. The evaluation shall be based on the technical content and presentation of the work.

<u>SEMESTER - IV</u>

24-508-0401: PROJECT DISSERTATION PHASE - II

Course Outcomes:

On completion of this course the student will be able to:

CO1. *Use different experimental techniques*
CO2. *Use different software/ computational/analytical tools*
CO3. *Design and develop an experimental set up/ equipment/test rig*
CO4. *Conduct tests on existing set ups/ equipments and draw logical conclusions from the results after analyzing them*
CO5. *Either work in a research environment or in an industrial environment*
CO6. *Become conversant with technical report writing*
CO7. *Present and convince their topic of study to the engineering community*

Course Articulation Matrix

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	3	2	3
CO2	3	3	3	3	2	3
CO3	3	3	3	3	2	3
CO4	3	3	3	3	2	3
CO5	3	3	3	3	2	3
CO6	3	3	3	3	2	3
CO7	3	3	3	3	2	3

1: Low 2: Moderate 3. Highly related

Guidelines:

It is a continuation of Project work started in the 3rd semester. The student has to submit the report in prescribed format and also present a seminar. The dissertation should be presented in standard format as provided by the department. The candidate has to prepare a detailed project report consisting of introduction of the problem, problem statement, literature review, objectives of the work, methodology (experimental set up or numerical details as the case may be) of solution and results and discussion. The report must bring out the conclusions of the work and future scope for the study. The work has to be presented in front of the examiners panel consisting of an approved external examiner, internal examiner and project guide as decided by the Head and PG course coordinator. The candidate has to be in regular contact with his guide. The project work shall be reviewed and evaluated periodically during the semester. A detailed project dissertation in the prescribed format shall be submitted at the end of the semester. All the test results, relevant design and engineering documentation shall be included in the dissertation. The evaluation shall be based on (i) Presentation of the work, (ii) Quality and content of the dissertation and (iii) Viva Voce.

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