B. Tech (Four-Year) Course Structure and Syllabi In Aerospace Engineering

(*As Per UG Ordinance with effect from July 2019*)

Department of Aerospace Engineering and Applied Mechanics

Indian Institute of Engineering Science and Technology, Shibpur

An Institute of National Importance

भारतीय अभियांत्रिकी विज्ञान एवं प्रौद्योगिकी संस्थान, शिवपुर

IIEST, Shibpur

आई आई ई एस टि, शिवपुर

Erstwhile B E College (Estd 1856)

Botanic Garden, Howrah, West Bengal, India - 711103

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B. Tech (Four-Year) Program In Aerospace Engineering:

Program Educational Objectives:

- To produce graduates with a strong foundation in aerospace engineering principles enabling them to analyze, design, and solve aerospace related problems.
- To equip students with practical and technical skills for using industry-standard softwares especially for the aerospace sector.
- To expose students to the interdisciplinary nature of aerospace engineering, such as mechanical engineering, electrical engineering, materials science, and computer science.
- To provide graduates with the ability to conduct applied research for the advancements in aerospace technologies.
- To nurture a sense of ethical responsibility and commitment towards the quality and safety in the aerospace industry.

Program Specific Outcomes:

- Graduates will be able to apply principles of aerodynamics, propulsion, structures and materials to design, analyze, and develop different aerospace systems.
- Graduates will have the ability to collect, analyze, and interpret experimental data and use computational tools for simulation and modeling in the design and analysis of aerospace systems.
- Graduates will also have a fundamental understanding of the control systems that ensure stability and performance in aircraft and spacecraft.
- Graduates will be capable of joining jobs at national and international aerospace industries.
- Graduates will have the motivation to engage themselves for research in the aerospace field at Masters and PhD level at national and international universities and research organisations.

COURSE STRUCTURE AND SYLLABI OF

B. TECH IN AEROSPACE ENGINEERING

Semester-wise Course Structure for Aerospace Engineering
4-year B.Tech Programme from 2019-20 Session onward

1st Semester

Sl. No	Course Name	Course code	Class Load/Week			Credit	Class load/ week	Marks
			L	T	P			
1.	Mathematics – I		3	1	0	4	4	100
2.	Chemistry/Physics		3/4	0	0	3/4	3/4	100
3.	Intro to Computing/Basic Electrical Engineering		3/4	0	0	3/4	3/4	100
4.	Mechanics/Ecology & Environment		4/3	0	0	4/3	4/3	100
5.	English/Sociology & Professional Ethics		3	0	0	3	3	100
	Theory Sub-total		**16/ 17**	**1**	**0**	**17/18**	**17/18**	**500**
6.	Chemistry Lab/Physics Lab		0	0	3	2	3	50
7.	Computer Lab/ Electrical Lab		0	0	3	2	3	50
8.	Drawing/Workshop		0	1/0	3	3/2	4/3	50
9.	NSS/NCC/PT/Yoga					R*		
	Practical Sub-total		**0**	**1/0**	**9**	**7/6**	**10/9**	**200**
	First Semester Total					**24**	**27**	**700**

*R: Required (Non-credit but with grade)

2nd Semester

Sl. No	Course Name	Course code	Class Load/Week			Credit	Class load/ week	Marks
			L	T	P			
1.	Mathematics – II		3	1	0	4	4	100
2.	Physics/Chemistry		4/3	0	0	4/3	4/3	100
3.	Basic Electrical Engineering/ Intro to Computing		4/3	0	0	4/3	4/3	100
4.	Ecology & Environment/ Mechanics		3/4	0	0	3/4	3/4	100
5.	Sociology & Professional Ethics/ English		3	0	0	3	3	100
	Theory Sub-total		**17/ 16**	**1**	**0**	**18/17**	**18/17**	**500**
6.	Physics Lab/Chemistry Lab		0	0	3	2	3	50
7.	Electrical Lab/Computer Lab		0	0	3	2	3	50
8.	Workshop/Drawing		0	0/1	3	2/3	3/4	50
9.	NSS/NCC/PT/Yoga					R*		
	Practical Sub-total		**0**	**0/1**	**9**	**6/7**	**9/10**	**200**
	Second Semester Total					**24**	**27**	**700**

*R: Required (Non-credit but with grade)

3rd Semester

Sl. No	Course Name	Course code	Class Load/Week			Credit	Class load/week	Marks
			L	T	P			
1.	Mathematics – III	MA 2101	3	0	0	3	3	100
2.	Fluid Dynamics	AE 2101	3	1	0	4	4	100
3.	Strength of Materials	AM 2101	4	0	0	4	4	100
4.	Dynamics	AM 2102	4	0	0	4	4	100
5.	Basic Flight Mechanics	AE 2102	3	0	0	3	3	100
	Theory Sub-total		**17**	**1**	**NIL**	**18**	**18**	**500**
6.	Fluid Dynamics Laboratory	AE 2171	0	0	3	2	3	50
7.	Strength of Materials Laboratory	AM 2171	0	0	3	2	3	50
8.	Machine Drawing	AM 2172	0	0	3	2	3	50
9.	Seminar/Mini Project -I	AE 2191	0	0	0	2	0	50
	Sessional Sub-total		**NIL**	**NIL**	**9**	**8**	**9**	**200**
	3rd Semester Total					**26**	**27**	**700**

4th Semester

Sl. No	Course Name	Course code	Class Load/Week			Credit	Class load/ week	Marks
			L	T	P			
1.	Fundamentals of Viscous Flow	AE 2201	3	1	0	4	4	100
2.	Advanced Strength of Materials	AE 2202	3	0	0	3	3	100
3.	Theory of Vibration	AE 2203	3	0	0	3	3	100
4.	Engineering Thermodynamics	AE 2204	4	0	0	4	4	100
5.	Aircraft Performance	AE 2205	3	0	0	3	3	100
	Theory Sub-total		**16**	**1**	**NIL**	**17**	**17**	**500**
6.	Computational Solid Mechanics Laboratory	AE 2271	0	0	3	2	3	50
7.	CAD Laboratory	AE 2272	0	0	3	2	3	50
8.	Vibration Laboratory	AE 2273	0	0	3	2	3	50
9.	Mathematical Modeling and Simulation Laboratory	AE 2274	0	0	3	2	3	50
	Sessional Sub-total		**NIL**	**NIL**	**12**	**8**	**12**	**200**
	4th Semester Total					**25**	**29**	**700**

5th Semester

Sl. No	Course Name	Course code	Class Load/Week			Credit	Class load/ Week	Marks
			L	T	P			
1.	Low Speed Aerodynamics	AE 3101	4	0	0	4	4	100
2.	Aircraft Stability and Control	AE 3102	4	0	0	4	4	100
3.	Numerical Method and Computational Tools	AE 3103	3	0	0	3	3	100
4.	Aircraft Dynamics and Navigation	AE 3104	4	0	0	4	4	100
5.	Composites and Structures	AE 3105	3	0	0	3	3	100
	Theory Sub-total		**18**	**NIL**	**NIL**	**18**	**18**	**500**
6.	Low Speed Aerodynamics Laboratory	AE 3171	0	0	3	2	3	50
7.	Aircraft Stability and Control Laboratory	AE 3172	0	0	3	2	3	50
8.	Numerical Method and Computational Tools Laboratory	AE 3173	0	0	3	2	3	50
	Sessional Sub-total		**NIL**	**NIL**	**9**	**6**	**9**	**150**
	5th Semester Total					**24**	**27**	**650**

6th Semester

Sl. No	Course Name	Course code	Class Load/Week			Credit	Class load/ Week	Marks
			L	T	P			
1.	High Speed Aerodynamics	AE 3201	4	0	0	4	4	100
2.	Theory of Propulsion	AE 3202	4	0	0	4	4	100
3.	Aerospace Structures	AE 3203	4	0	0	4	4	100
4.	Introduction to FEM and Applications	AE 3204	4	0	0	4	4	100
5.	Orbital Mechanics	AE 3205	4	0	0	4	4	100
	Theory Sub-total		**20**	**NIL**	**NIL**	**20**	**20**	**500**
6.	High Speed Aerodynamics Laboratory	AE 3271	0	0	3	2	3	50
7.	Propulsion Laboratory	AE 3272	0	0	3	2	3	50
8.	Aircraft Design and Flight Training	AE 3273	0	0	3	2	3	50
	Sessional Sub-total		**NIL**	**NIL**	**9**	**6**	**9**	**150**
	6th Semester Total					**26**	**29**	**650**

7th Semester

Sl. No	Course Name	Course code	Class Load/Week			Credit	Class load/ Week	Marks
			L	T	P			
1.	Computational Fluid Dynamics	AE 4101	4	0	0	4	4	100
2.	Jet and Rocket Propulsion	AE 4102	3	0	0	3	3	100
3.	Core Elective – I **(LIST-I)**	**(LIST-I)**	3	0	0	3	3	100
4.	Open Elective – I **(HSS-II)**		3	0	0	3	3	100
	Theory Sub-total		**13**	**NIL**	**NIL**	**13**	**13**	**400**
6.	Aerospace Structures Laboratory	AE 4171	0	0	3	2	3	50
7.	Aircraft Design and Manufacturing Techniques	AE 4172	0	0	4	2	4	50
8.	B. Tech Project/1	AE4191	0	0	0	4	2	100
9.	Internship from 6th Sem (Evaluation)	AE4192	0	0	0	2	0	50
	Sessional Sub-total		**NIL**	**NIL**	**7**	**10**	**9**	**250**
	7th Semester Total					**23**	**22**	**650**

(LIST-I) (Core Elective – I)

1. Aerospace Structural Dynamics (AE 4121)
2. Satellite Attitude Dynamics (AE 4122)

8th semester

Sl. No	Course Name	Course code	Class Load/Week			Credit	Class load/ Week	Marks
			L	T	P			
1.	Turbulent Flow	AE 4201	4	0	0	4	4	100
2.	Core Elective – II (**LIST-II)**	(**LIST-II)**	3	0	0	3	3	100
3.	Open Elective II **(LIST-III)**	**(LIST-III)**	3	0	0	3	3	100
	Theory Sub-total		10	NIL	NIL	10	10	300
4.	B. Tech Project /2	AE 4291	0	0	0	8	2	200
5.	Seminar	AE 4292	0	0	0	2	0	50
6.	Comprehensive Viva	AE 4293	0	0	0	2	0	100
	Sessional Sub-total		NIL	NIL	NIL	12	2	350
	8th Semester Total					22	12	650
		TOTAL CREDIT (All Semesters) =194						

(LIST-II) (Core Elective -II)

1. Spacecraft Dynamics (AE 4221)
2. Fracture Mechanics (AE 4222)
3. Aeroelasticity (AE 4223)
4. Fundamentals of Combustion in Propulsion (AE 4224)
5. Aircraft Dynamics – A Modeling Approach (AE 4225)
6. Computational Low Speed Aerodynamics (AE 4226)
7. Mechatronics and Avionics (AE 4227)

(LIST-III) (Open Elective II)

1. Finite Element Method (AE 4261)
2. Nonlinear Dynamics (AE 4262)
3. Basics of Parallel Computation (AE 4263)

Total credit:	**24 +**	**24 +**	**26 +**	**25 +**	**24 +**	**26 +**	**23 +**	**22**	**= 194**
Semester:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	

1st and 2nd SEMESTER SYLLABUS

B. TECH
IN
AEROSPACE ENGINEERING

Mechanics (AM 1101/ AM1201)
(Common course for all Engineering Students)

Contact Period : 4L per week **Full Marks : 100 [Credit: 04]**
Prerequisite : None

Sl No.	Article	No. of Classes
1	**Introduction to Statics** : Mechanics; Basic Concepts; Scalars and Vectors; Newton's laws	02
2	**Force Systems** : Force Systems in Two Dimensions; Moments and Couples; Resultants and Components	04
3	**Equilibrium** : Free Body Diagram, Conditions for Equilibrium in Two Dimensional Force Systems	03
4	**Structures** : Plane Trusses and Frames	07
5	**Distributed Force Systems** : Center of Mass; Centroid of Lines; Areas and Volumes; Theorems of Pappus; Area Moments of Inertia	06
6	**Friction** : Friction – Application to wedges	06
7	**Kinematics of Particles** : Two Dimensional Particle Kinematics in Rectangular Co-ordinates, Cylindrical Co-ordinates and in terms of Normal and Tangential Components	11
8	**Kinetics of Particles** : Conservation Laws – Approaches in terms of Force, Mass and Acceleration; Work and Energy; Linear Impulse and Momentum – Impact; Angular Impulse and Momentum – Central Force Motion;	11
9	Introduction to Vibration	02
	Total	**52**

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

- Obtain the equivalent force – couple system of a given system
- Analyze the equilibrium state of a particle and rigid body
- Estimate the moment of inertia of composite area about centroidal or any arbitrary axis
- Determine the velocity and acceleration of a particle in rectangular and cylindrical coordinate systems of rigid bodies in general plane motion.

Text Book :
Engineering Mechanics Statics (Vol. I) and Dynamics (Vol. II) – J.L. Meriam & L.G. Kraige

Reference Books :

Engineering Mechanics Statics and Dynamics – I.H. Shames
Vector Mechanics for Engineers Statics – F.P. Beer and E.R. Johnston Jr.
Vector Mechanics for Engineers Dynamics – F.P. Beer and E.R. Johnston Jr.

Drawing Practice (AM 1171 / AM1271)
(Common course for all Engineering Students)

Contact Period: 0-1-3 (L-T-P) **Prerequisite: None** **Full Marks: 50**
[Credit: 03]

Sl. No.	Module Name	Detailed Topics	No. of Class
1	**Introduction to Engg. Drawing**	Geometric Constructions, Types of Lines, Symbols, Hatchings, Dimensioning Styles and Copy Figure	**04**
2	**Projection of Points, Lines & Surfaces**	Concept of Projection Planes and Corresponding Methods, Concept of True Length and True Angles, Plan and Elevation Lengths and Angles only in First angle Projection, Projection of Plane Surfaces with regular Geometric Boundaries	**10**
3	**Projection of Solids**	Projection of Regular Solids resting on H.P. on corners, sides and bases.	**10**
4	**Section of Solids**	Sectional Views of Regular Solids, Concept of True Shapes	**08**
5	**Orthographic Projection**	Conversion of Pictorial Views to Two Dimensional Views on Planes of Projections	**06**
6	**Isometric Projection**	Concept of Isometric Scales, Isometric View and Isometric Projection	**10**
7	**End Test**		**04**
	Total		**52**

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

- Interpret and create 2D and 3D engineering drawings.
- Use standard drawing conventions and scales effectively.
- Apply geometric constructions, orthographic projections, and isometric views.
- Communicate design ideas clearly through graphical methods.

Reference Books:

1. Engineering Drawing by N. D. Bhatt
2. Engineering Drawing And Graphics by K.Venugopal

3rd SEMESTER SYLLABUS

B. TECH
IN
AEROSPACE ENGINEERING

FLUID DYNAMICS (AE 2101)

(Only for AE)

Contact Period: 3L + 1T per week **Full Marks:100 [Credit – 4]**

Prerequisites: Engineering Mechanics, Mathematics (ODE, PDE, Vector Calculus)

Sl No.	Article	No. of Classes
1	**Introductory concepts:** Continuum approximation; Lagrangian and Eulerian description of motion, particle derivative; Fluid properties (viscosity, compressibility, speed of sound), dimensions and units; Flow visualization; Classification of fluid flow; Basic equation of fluid statics, manometers, pressure variation in atmosphere; Fluids in rigid-body motion - uniform linear acceleration and rigid-body rotation	6 + 3*
2	**Control volume analysis:** System and control volume, Reynolds transport theorem, Conservation equations for mass, momentum and energy in integral form, body and surface forces on a C.V., continuity and momentum balance in unidirectional flow, momentum correction factor, steady mechanical energy balance; Idealized theory of propeller; Noninertial reference frame (e.g. rocket motion)	8 + 3*
3	**Differential analysis of fluid motion:** Continuity equation in Cartesian, cylindrical and spherical reference frames, Stream function; **Kinematics** - translation, rotation and deformations of a fluid element, vorticity, volume dilation, incompressible flow, rate of strain tensor, acceleration of a particle; **Equation of motion** - stress at a point, mean pressure, momentum conservation equation from an infinitesimal C.V., Stokes' law of viscosity, Navier-Stokes equation, exact solutions for incompressible flow in a parallel plate channel (Couette flow and Poiseuille flow), circular pipe (Hagen-Poiseuille flow).	12 + 2*
4	**Inviscid flow theory:** 3D Euler's equation, equations of motion along a streamline and normal to streamline direction, unsteady Bernoulli's equation; **Potential flow** - Irrotational flow and velocity potential, elementary potential flow patterns – uniform stream, line source and sink, line vortex, Principle of superposition (flow past a Rankine half body); Equation of motion and Bernoulli's equation for potential flow	6 + 2*
5	**Internal incompressible flow:** Incorporation of viscous loss terms in Bernoulli's eq., kinetic energy correction factor; Darcy's equation for fully developed pipe flow, Moody diagram, flow rate-pressure drop relations for laminar and turbulent flow, hydraulic diameter, minor losses at pipe fittings (sudden expansion, sudden contraction, flow through an orifice, etc.); **Flow measurements** (application of Bernoulli's theory) – Pitot tube and Pitot-static tube, orificemeter, venturimeter	7 + 3*
	Total	**52**

*Number of classes dedicated for solving Tutorial problems

Course Outcomes:

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

- learn the fundamentals concepts of Fluid dynamics (e.g., Reynolds transport theorem, flow kinematics, steam function, Navier-Stokes equation, Euler's equation and potential flow theory, boundary layer, pipe flow and head loss)
- analyze and solve engineering problems, using the analytical tools introduced though the course
- learn about the real-life applications of the theory

Books:

R W Fox and A T McDonald, Introduction to Fluid Mechanics, Wiley India
F M White, Fluid Mechanics, McGraw-Hill International

Strength of Materials (AM 2101)

(Common Course for AE & ME)

Contact Period: 4L per week **Full Marks: 100 [Credit – 04]**

Sl No.	Article	No. of Classes
1.	Stress, Strain, stress at a point, stress-strain diagrams of ductile and brittle materials, Hooke's Law, Factor of Safety	03
2.	Elastic constants, Poisson's ratio, pure shear, shear modulus, bulk modulus, relation among the Elastic constants	04
3.	Problems related to stress and strains, thermal stress problems	04
4.	Bi-axial stress, principal stress and strain, thin-walled pressure vessels, rings subjected to internal pressure	04
5.	Shear force and bending moment diagrams, bending of beams due to transverse load, Euler-Bernoulli's Equation, section modulus, simple bending formula, applications	09
6.	Shear stresses in beams, built-up sections, stiffened sections	05
7.	Complex stress and strain, Mohr's circle	05
8.	Torsion of circular shaft & applications	03
9.	Combined bending, torsion and axial thrust & applications	03
10.	Deflection of beams subjected to transverse forces – integration method, area-moment theorems	05
11	Energy method – Castigliano's theorem	03
12	Elastic theories of failure & applications	04
	Total	**52**

Course Outcomes:

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

- Explain the fundamental concepts of stress, strain, and their relationship in materials under different loading conditions.
- Apply the principles of equilibrium of deformable bodies to analyze axial, torsional, and bending stresses in structural elements.
- Analyze shear force and bending moment distributions in beams and determine bending and shear stresses.
- Evaluate the deflection of beams using methods like double integration, moment-area and Castigliano theorems.
- Assess the failure theories (Maximum Normal Stress, Maximum Shear Stress, Von Mises) for structures and design simple structural elements (e.g., beams, shafts, columns) under axial, bending, and torsional loads within safe limits using suitable factors of safety.
- Interpret and correlate material behavior from experimental stress analysis techniques, such as strain rosette and draw Mohr's circle.

Text Book: 1. Elements of Strength of Materials - S.P. Timoshenko and D.H. Young.

Reference Books:

1. Mechanics of Materials – E. Popov
2. A Text Book of Strength of Materials – R.K. Bansal
3. Strength of Materials – F.P. Beer and E.R. Johnston Jr.
4. Strength of Materials (Vol. 1) – D.S. Prakash Rao

Dynamics (AM 2102)

(Common Course for AE & ME)

Contact Period: 4L per week **Full Marks: 100 [Credit – 04]**
Prerequisite: Engineering Mechanics

Sl No.	Article	No. of Classes
1.	**Introduction** : Kinematics and dynamics, frames of reference, coordinate systems, particle and rigid bodies, scalars, vectors and tensors , Illustrative problems	02
2.	**Kinetics of systems of particles and variables mass problems** Illustrative problems	10
3.	**Kinetics of particles in accelerating frame of reference** : • Frames with Linear Acceleration, D'Alembert's Principle • Motion in Rotating Frame of Reference Illustrative problems	08
4.	**Dynamics of rigid bodies in plane motion** : • Definition of Rigid Bodies and Kinematic constraints • Kinematics of Rigid Bodies – Translational Motion, Pure Rotation and General Motion • Linear and Angular Momentum, Kinetic energy • FBD and Laws of Motion • Conservation Principles – linear and angular Momentum, Energy • Impulsive Forces and Moments Illustrative problems	15
5.	**Dynamics of Motion in Three-dimension** : • Chasle's Theorem and Spheric Motion • Angular Momentum and Inertia Tensor, Kinetic Energy • Free Motion of an Axisymmetric Body – Body cone and Space cone • Euler's Equation, Modified Euler's Equation, Euler Angles, Gyroscopic Acion. Illustrative problems	17
	Total	**52**

Course Outcomes:

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

- Determine the kinematic relationships between position, velocity, and acceleration for two-dimensional motion of systems of particles and rigid bodies
- Apply Newton's equation in two dimensions to calculate the motion due to applied forces or to calculate the forces resulting from a specified motion.

- Analyze the two-dimensional motion of particles and rigid bodies using conservation laws for energy, momentum, and angular momentum.
- Apply dynamics concepts to the design of simple machines and structures to accomplish a specific task

Books:

1. Engineering Mechanics: Dynamics – Meriam & Kraige

Basic Flight Mechanics (AE 2102)
(Only for AE)

Contact Period : 3L per week **Full Marks : 100 [Credit – 03]**

Prerequisite : None

1.	**Airfoils, Wings and Other Aerodynamic Shapes:** Airfoil Nomenclature; Finite Wings; Swept Wings; Delta Wings; Mechanisms for High Lift.	03
2	**Aerodynamic Interactions:** Force, Moment and Pressure Coefficients; Lift and Drag, Drag Polar	04
3	**Elements of Propulsion:** Introduction; Propeller; Reciprocating Engine; Jet Propulsion; Turbojet Engines; Turbofan Engines	05
4	**Elements of Compressible Flow:** One Dimensional Flow Equations of Conservation Principles; SomeConveniently Defined Flow Parameters; Alternative Forms of Energy Equations; Normal and Oblique Shock Relations;	03
5	**Static Stability and Control:** Basic Concepts of Airplane Stability and Control; Static Stability and Dynamic Stability; Controllability.	02
6	**Longitudinal Stick–Fixed Static Stability and Control:** Criterion of Longitudinal Static Stability, Contribution of Aircraft Components, Wing Contribution, Horizontal Tail Contribution, Fuselage Contribution, Power Plan Contribution, Stick-Fixed Neutral Point, StaticMargin.	04
7	**Longitudinal Control** Elevator, Elevator Power, Elevator Effectiveness, Elevator Angle to Trim.	04
8	**Longitudinal Stick-Free Static Stability** Hinge Moments and Effect of Freeing the Stick, Trim Tab, Stick Forces and Stick Force Gradients, Analysis of Stick-Free Static Stability, Floating Angle of Elevator, Static Stability in Stick-Free Condition, Stick-Free Neutral Point, Effect of Acceleration, Stick-Fixed Manoeuvre Point; StickForce Gradient in Pull-Up; Stick-Free Manoeuvre Point.	05
9	**Directional Static Stability and Control** Criteria of Directional Static Stability, Side Slip and Yaw, Contribution of Wing, Fuselage, Power and Vertical Tail to Directional Stability, Pedal Fixed and Pedal-Free Directional Stability, Directional Control, Adverse Yaw and Cross Wind Take-off and Landing, Control in asymmetric power, steady flight after engine failure and minimum control speed, Need for rudder deflection in a coordinated turn ,Effect of large angle of side slip, rudder lock and dorsal fin, Prevention of rudder lock	05

10	**Lateral Static Stability and Control** Criteria of Lateral Static Stability, Rolling Moment, Dihedral Effect and Contributions of Wing, Fuselage, Vertical Tail, Propeller and Flaps, Roll Control, Aileron, Rolling Moment due to Aileron, Damping Moment, Rate of Roll, Aileron Power, Aerodynamic Balancing, Tabs, Elevons.	05
	Total	**39**

Course Outcomes:

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

- Analyze aircraft static stability: Students will be able to determine the static stability of an aircraft, including longitudinal, lateral, and directional stability.
- Understand hinge-free stability: Students will be able to analyze the stability of control surfaces without hinges, including the effects on aircraft behavior.
- Apply elementary aerodynamics: Students will be able to apply basic aerodynamic principles to predict aircraft behavior, including lift, drag, and thrust.
- Predict aircraft response: Students will be able to predict aircraft response to control inputs and disturbances.
- Evaluate aircraft stability characteristics: Students will be able to evaluate the stability characteristics of an aircraft, including stick-fixed and stick-free stability.

Books:

1. Introduction to flight –JD Anderson
2. Flight without formula-AC Kermode
3. Mechanics of Flight – W. F. Philips, Willey India
4. Flight Mechanics and Automatic control- RC Nelson

FLUID DYNAMICS LABORATORY (AE 2171)
(Only for AE)

Contact Period: 0L-0T-3P per week **Full Marks: 50 [Credit – 02]**

Sl No.	Name of experiments	No. of Classes
1.	Verification of Bernoulli's theorem	03
2.	Force of impact of jet on vanes	03
	Viva voce on experiments 1 and 2	03
3.	Reynolds experiment	03
4.	Calibration of an orifice meter	03
	Viva voce on experiments 3 and 4	03
5.	Determination of orifice coefficients	03
6.	Determination of settling velocity of spheres	03
	Viva voce on experiments 5 and 6	03
7.	Friction losses in commercial pipes	03
8.	Investigation of the boundary layer on a flat plate with and without pressure gradient	03
9.	Arrear class	03
	Viva voce on experiments 7, 8 and arrear	03
	Total	**39**

Course Outcomes:

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

- Students learn to apply fundamental principles like Bernoulli's equation and the conservation of mass and energy to solve real-world fluid flow problems and understand the behaviour of fluids in various engineering applications
- Students will develop practical skills in conducting experiments, collecting data, analyzing results, and reporting findings

Strength of Materials Laboratory (AM 2171)

(Common for AE& ME)

Contact Period : 0L-0T-3P **Full Marks : 50 [Credit – 02]**

Sl No.	Name of experiments	No. of Classes
1.	Introduction to Equipment and Facilities	03
2.	Rockwell Hardness Test	03
3.	Brinell Hardness Test	03
4.	Tension Test of Metals	06
5.	Experiment on Strain Hardening of Metals	03
6.	Torsion Test of Circular Shaft	03
7.	Experiment on Impact Test	03
8.	Buckling or Critical Load for Long Column	03
9.	Fatigue Testing of Metals (Lecture & Demonstration)	03
10.	Measurement of Beam Deflection Using Dial Gauge	03
	End Test	03
	Viva voce	03
Total		**39**

Course Outcomes:

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

- Know about the operational details of various testing machines for materials.
- Analysis of structural members subjected to tension, torsion, bending, strain hardening and fatigue using the fundamental concepts of stress, strain, and elastic behaviour of materials.
- Write a technical laboratory report and to interpret technical graphs.

Machine Drawing (AM 2172)
(Common course for AE & ME)

Full paper: 0L – 0T – 3S **Full Marks: 50 [Credit – 02]**
Prerequisite: Elementary Knowledge of Engineering Drawing

Sl.	Article	No. of Classes
1.	Development of Surfaces	06
2.	Rivet Joints, Nuts & Bolts	06
3.	Interpenetration of Solids	06
4.	Section of Machine Parts	03
5.	Component drawing and Assembly drawing of Machines	15
6	End Test	3
Total		**39**

Course Outcomes:

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

- Understand and apply the principles of machine drawing and represent mechanical components using standard drawing conventions.
- Interpret orthographic views, sectional views, and dimensioning systems used in machine drawings.
- Visualize and communicate design ideas effectively through technical drawings.
- Analyze and understand the functional relationships between assembled components in a machine.

Suggested readings: 1. Engineering Drawing – N.D. Bhatt
2. Engineering Graphics – Venugopal
3. Machine Drawing – N.D. Bhatt

Mini Project I (AE 2191)

Full Marks: 50 [Credit – 02]

This will be individual/small group project on simple Aerospace Engineering problems, primarily to be acquainted with complete problem solving and report writing practice.

4th SEMESTER SYLLABUS

B. TECH
IN
AEROSPACE ENGINEERING

Fundamentals of Viscous Flow (AE 2201)
(Only for AE)

Contact Period: 3L + 1T per week **Full Marks**: **100** [**Credit** – 4]
Prerequisites: Fluid Dynamics (AE2101)

Sl No.	Article	No. of Classes
1	**Dimensional analysis and Similitude:** Buckingham's Pi theorem; Nondimensionalisation of Navier-Stokes equations: emergence of dimensionless parameters and their physical interpretation; **Similitude** - geometric, kinematic and dynamic similarity, model testing in laboratory	5 + 2*
2	**Analytical solution of equation of motion**: boundary conditions for viscous flow, examples of steady laminar flow driven by shear, pressure gradient, and gravity, flow between concentric cylinders, unsteady flow – Stokes' 1st problem (similarity solution), low-Re flow (creeping motion) over a sphere; Lubrication theory	9 + 1*
3	**Boundary layer theory and related topics**: Boundary layer approximation, Laminar boundary layer equations and characteristic boundary layer thickness, scaling estimates of wall shear and friction coefficients (local and overall), displacement thickness and momentum thickness; **Integral method**: Von Karman momentum integral equation and its applications; **Exact solution** (similarity method) of laminar boundary layer eq. over a flat plate; Boundary layer transition, **Turbulent boundary layer** equations, structure of turbulent boundary layer – wall layer, outer layer and overlap layer, viscous sublayer, hydraulically smooth and rough surfaces, Integral estimates for turbulent boundary layer flow over a flat plate, **Boundary layer separation**: effect of pressure gradient on boundary layer velocity profile, Prediction of laminar separation point (Thwaites' correlation-based method), Methods of preventing/delaying boundary layer separation	11 + 3*
4	**Flow over Immersed Bodies**: forces and moments on a body, drag and lift, friction and pressure drag, streamlined body and blunt body; Flow past a smooth cylinder (different Reynolds number regimes, vortex street and Strouhal number, C_D vs. Re plot), force coefficients and characteristic area for some regular and irregular shaped bodies, **Forces on lifting bodies**: aircraft and airfoil, aerodynamics of sports ball (cricket and golf)	4 + 3*
5	**Thermal boundary layer and heat transfer:** Energy equation; Forced convection – thermal boundary layer equation, Reynolds' analogy, flat plate in parallel flow (solution by energy integral method), correlations for turbulent flow, cylinder in cross flow; Internal flows – concept of thermally fully developed flow, fully developed channel flow with constant wall heat flux and viscous dissipation, turbulent flow in pipes; Free convection along a vertical isothermal plate – governing equation, recognition of dimensionless terms, and solution by integral method.	10 + 4*
	Total	**52**

*Number of classes dedicated for solving Tutorial problems

Course Outcomes:

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

- Develop an understanding of the concepts of boundary layer, lubrication theory, drag and lift, thermal boundary layer, etc.
- Improve their overall analytical ability as both exact and approximate methods of the solution are discussed
- Learn dimensional analysis and scaling laws and their applications in wind tunnel testing and many more applications
- Learn design aspects of various devices and instruments (for example, drag reduction, lift generation, enhancement of heat transfer in practical scenario)

Books:

1. Viscous Fluid Flow, F.M. White, McGraw-Hill International.
2. Boundary Layer Theory, H. Schlichting, McGraw-Hill.
3. Fundamentals of Heat and Mass Transfer – F. P. Incropera and D. P. Dewitt, John Wiley.
4. An Introduction to Fluid Dynamics, G.K. Batchelor, Cambridge University Press.

Advanced Strength of Materials (AE 2202)
(Only for AE)

Contact Period: 3L per week **Full Marks: 100 [Credit – 03]**

Prerequisites: Strength of Materials

Sl. No.	Article	No. of Classes
1	**Basic Elasticity** : Introduction to tensor – generalized coordinate transformation – stress tensor at a point – principal stress & stress invariant – analysis of strain – constitutive & compatibility equation in 3D Cartesian coordinate – introduction to plane stress – introduction to plane strain.	09
2	**Virtual Work:** Principle of VW for particle & rigid body – VW done by axial forces, shear forces, bending moment and torsion – application to beams and trusses	08
3	**Energy Methods** : Strain energy due to axial force, bending and torsion with applications – Complimentary energy – total potential energy; total complimentary energy and principles of stationary value – application to determinate & indeterminate problems (beams, frames, rings)	10
4	**Structural Instability** : Short and long columns, critical load, column with eccentric loading – transversely loaded column (beam-column) – energy method for buckling loads in column – effect of initial imperfection in column & Southwell plot – complete diagonal tension field beam – incomplete diagonal tension field beam – applications.	12
	Total	**39**

Course Outcomes:

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

- This course provides a clear and vivid understanding of real life structures by offering knowledge of analysis of basic structural components. Analysis and idealization of real life structures enables students to write proper computer codes. Truly speaking, this course strengthens the foundation of structural analysis and enhances the analytical understanding.

Books recommended:

1. Elasticity, Martin H. Sadd
2. Theory of Elasticity, Timoshenko & Goodier
3. Aircraft Structures, T.H.G. Megson
4. Applied Elasticity, Zhi Lun Xu
5. Foundations of Solid Mechanics, Y.C. Fung

Theory of Vibration (AE 2203)

(Only for AE)

Contact Period : 3L per week **Full Marks : 100 [Credit – 03]**
Prerequisite : Engineering Mechanics and Strength of Materials
Utility: This course provides the basic knowledge of vibration and control of vibration which will be required for design of engineering machines and structures.

Sl No.	Article	No. of Classes
1.	Introduction; Oscillatory motion – Harmonic motion, Periodic motion, Vibration Terminology	02
2.	Free Vibration of Single Degree of Freedom System : Vibration model and equations of motion, Natural frequency, Energy method, Rayleigh method, Different Kinds of Damping	05
3.	Forced vibration of Single Degree of Freedom System: Forced harmonic vibration, Rotating unbalance, Rotor unbalance, Whirling of rotating shafts, Support motion, Vibration isolation, Energy dissipation, Vibration measuring instruments	08
4.	Multi-degree of freedom systems: Normal mode vibration, Coordinate coupling, Forced harmonic excitation	06
5.	Properties of vibrating systems: Flexibility matrix, Stiffness matrix, Stiffness of beam elements, Eigenvalues and eigenvectors, Orthogona properties of eigenvectors, Modal matrix, Modal damping in forced vibration	10
6.	Normal mode vibration of continuous systems: Vibrations of rods, Euler equation of beams	05
7.	Approximate numerical methods: Rayleigh method, Dunkerley's method	03
	Total	**39**

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

- Students are able to do vibration analysis of different structures
- Able to predict the methods to avoid failure of the structure due to vibration
- Acquire fundamental theoretical and practical knowledge to pursue higher study.

Books:

1. W T Thompson, Theory of Vibration with Applications, George Allen
2. L Meirovitch, Analytical Methods in Vibration, MacMillan
3. A C Fung, Introduction to Aeroelasticity,
4. R L Bisplinghoff, H Ashley, Principle of Aeroelasticity, Wiley
5. E H Dowell and H C Curtiss, A Modern Course on Aeroelasticity, Kluwer Academic Publishers

ENGINEERING THERMODYNAMICS (AE 2204)
(Only for AE)

Contact Period: 4L per week **Full Marks: 100 [Credit – 4]**
Prerequisite: None

Sl No.	Article	No. of Classes
1.	**Introduction to classical thermodynamics**: Energy conversion, Internal energy, Microscopic vs. Macroscopic viewpoint; Thermodynamic system and control volume, Properties and State of a substance, Processes and Cycles; Thermodynamic equilibrium, The Zeroth law of thermodynamics; Quasi-equilibrium process	03
2.	**Properties of a pure substance**: Phase equilibrium in a pure substance, Thermodynamic surfaces, Equation of State, Thermodynamic tables	02
3.	**Work and Heat interactions**: Work, Simple compressible system, Work done at a moving boundary; Other modes of work transfer; Heat, Comparison of heat and work.	03
4.	**First law of thermodynamics**: 1^{st} law for a Cycle, 1^{st} law for a control mass, Internal energy – a thermodynamic property, Enthalpy, Specific heats; 1^{st} law for a control volume – the steady-state steady-flow (SSSF) model, the transient flow model, and their applications.	06
5.	**Second law of thermodynamics**: Limitations of 1^{st} law, Statements of 2^{nd} law of thermodynamics, 1^{st} law (thermal) efficiency and C.O.P; Reversible and irreversible processes; The Carnot cycle; Thermodynamic temperature scale; Inequality of Clausius, Entropy – a thermodynamic property, 2^{nd} law equation for a control mass, Principle of the increase of entropy; Thermodynamic property relations, Reversible polytropic processes for an ideal gas; 2^{nd} law equation for a control volume - The steady-state steady-flow (SSSF) model, the transient flow model; Thermal efficiencies of nozzle, turbine and compressor.	10
6.	**Irreversibility and Availability**: Reversible work, Evaluating irreversibility in a general transport process, Availability or Exergy, Exergy balance for a closed system, Exergy balance for control volumes at steady state, 2^{nd} law efficiency, The Maxwell relations; Behaviour of real gases	06
7.	**Power cycles**: Rankine cycle; Brayton cycle, regenerator, Air standard cycle for jet propulsion; Working principle of Spark-ignition and Compression-ignition engines, Otto cycle, Diesel cycle	06
8.	**Elements of Heat Transfer:** Modes of heat transfer, Derivation of generalized equation in Cartesian, cylindrical and spherical coordinates. **Conduction:** Fourier's law, One dimensional steady state conduction, heat conduction through plane and composite walls, cylinders and spheres, critical radius of insulation for cylinder and sphere, lumped heat capacity analysis, transient heat conduction in solids, types of fin, heat flow through rectangular fin, infinitely long fin, fin insulated at the tip and fin losing heat at the tip. **Radiation:** Absorptivity, reflectivity and transmissivity, black, white and grey body, emissive power and emissivity, laws of radiation – Planck, Stefan-Boltzmann, Wein's displacement, Kirchhoff's law, Lambert's cosine law, Radiation heat exchange between black bodies, shape factor.	10
9.	**Combustion thermodynamics**: Mixture of ideal gases, fugacity; Fuels, Combustion process, Enthalpy of formation, First-law analysis of reacting systems, Adiabatic flame temperature, Higher and lower heating value; Third law of thermodynamics	06

	Total	**52**

Course Outcomes:

Upon successful completion of this course, the students will be able to:

- Define and explain basic thermodynamic properties and concepts including system, control volume, state, process, and cycle.
- Interpret and use thermodynamic property tables and equations of state for pure substances.
- Analyze work and heat interactions in thermodynamic systems.
- Apply the first law of thermodynamics to closed and open systems.
- Understand and apply the second law of thermodynamics, including the concepts of entropy and exergy.
- Evaluate the performance of thermodynamic cycles used in power generation and propulsion systems.
- Analyze chemical reactions and combustion processes from a thermodynamic perspective.

Books recommended:

1. Fundamentals of classical thermodynamics – G.J. Van Wylen & R.R. Sonntag, Wiley
2. Engineering Thermodynamics – P. K. Nag, Tata-McGraw Hill
3. Internal Combustion Engines – V. Ganesan, McGraw Hill India Pvt. Ltd.

Aircraft Performance (AE 2205)
(Only for AE)

Contact Period : 3L per week **Full Marks : 100 [Credit – 03]**
Prerequisite : Basic Flight Dyanmics, Dynamics

Sl.	Article	No. of classes
1	**Introduction**	01
4	**Airplane Performance:** **The Equation of Motion**	02
5	**Airplane Performance in Steady Flight:** Equations; Thrust required; Fundamental Parameters; Thrust available and maximum velocity; Power required, Power available and maximum velocity; Rate and Time to climb; Range and Endurance. Problems	18
6	**Airplane Performance in Accelerated Flight:** Level Turn; Pull-up and Pull-down Maneuvers; Energy Concepts – Accelerated Rate of Climb; Take off Performance; Landing Performance. Problems	18
	Total	**39**

Course Outcomes:
Upon completing this course, students will be able to:

- Define and explain the basic principles governing aircraft motion and performance.
- Derive and apply the equations of motion for aircraft in steady and accelerated flight.
- Calculate thrust and power requirements for different flight regimes and aircraft configurations.
- Analyze performance metrics such as rate/time of climb, range, and endurance for various aircraft.
- Evaluate aircraft behavior during level turns, pull-up/pull-down maneuvers, and other non-steady flight conditions.
- Estimate takeoff and landing performance under different operational scenarios.
- Solve practical aircraft performance problems using theoretical concepts and data.

Books recommended :

1. Aircraft Performance and Design, J. D. Anderson, Jr., McGraw-Hill

Computational Solid Mechanics Laboratory (AE 2271)

(Only for AE)

Contact Period: 0L-0T-3P per week **Full Marks: 50 [Credit – 02]**

Prerequisite: Strength of Materials

Sl No.	Name of experiments	No. of Classes
1	Introduction, discretization, approximation and exact solutions, development of stiffness matrix of spring and bar elements and their assembling's	06
2	Introduction to ANSYS Workbench, pre-processing, meshing, structural analysis, post-processing	03
3	Exercises using ANSYS Workbench: stress concentration problems, contact of aircraft engine blade and disc, deflections of an aircraft wing box	09
4	Introduction to ANSYS APDL, pre-processing, solution, general post-processing	06
5	2D and 3D Problems using ANSYS APDL	12
	Viva voce	3
Total		**39**

Course Outcomes:

Upon completing this course, students will be able to:

- Use finite element analysis software to model and analyse solid mechanics problems having structural and mechanical components.
- Interpret the results of simulations to assess stress, strain, and deformation.
- Validate simulation results by comparing them with theoretical predictions and experimental data.

References:
1. A First Course in the Finite Element Method, Daryl L. Logan, 5th edition, 2012
2. ANSYS 19.2 documentation

CAD Laboratory (AE 2272)
(Only for AE)

Contact Period : 0L- 0T- 3P per week **Full Marks : 50 [Credit – 02]**

Prerequisite: NIL

Sl No.	Name of experiments	No. of Classes
1	Introduction to CAD, Geometric Modelling, Parameterization, 2D and 3D Modelling using relevant CAD packages: Exercises	36
	Viva voce	3
	Total	**39**

Course Outcomes:

Upon completing this course, students will be able to:

- Students will develop proficiency in creating 2D and 3D models using CAD software.
- Students will apply design constraints and standards to produce accurate and functional engineering drawings.
- Students will demonstrate the ability to perform parametric modeling and assemble parts for complete design representation.

Vibration Laboratory (AE 2273)
(Only for AE)

Contact Period : 0L- 0T-3P per week **Full Marks : 50 [Credit – 02]**

Sl No.	Name of experiments	No. of Classes
1.	Introduction to Different Components of Fundamental Vibration Trainer	03
2.	Detailed demonstration of Software related to Different Experiments	03
3.	Familiarisation to Data Acquisition Device	03
4.	Demonstration of different components of Work Bench	03
5.	Experiment onVibration of Single DOF Systems – i) Basic Characteristics, ii) Harmonic Excitation	03
6.	Determination of Damping ratio for SDOF system with damped vibration	03
7.	Base Excitation Experiment	03
8.	Reporting on experiments of SDOF systems	03
9.	Experiment on Vibration of Two DOF Systems	03
10.	Experiment on Torsional Vibration	03
11.	Beam Lateral Vibration - Concept of ODS	03
12.	Demonstration of Tuned Mass Damper System	03
13.	Viva voce	03
	Total	39

Course Outcomes:

Upon completing this course, students will be able to:

- Students will be able to determine the vibration characteristics of a system like natural and damped frequencies, damping present in the system, stiffness of spring with observed natural frequency, ODS as well as natural frequencies of a continuous system. They will also be able to predict the effective measures to reduce the transmissibility and amplitude of vibration.

Mathematical Modeling and Simulation Laboratory (AE 2274)
(Only for AE)

Contact Period: 0L-0T-3P per week **Full Marks : 50 [Credit – 02]**

Pre-requisite: Knowledge of Computer Programming and Higher Mathematics

Objective: Numerical solutions of linear and non-linear algebraic equations, ordinary differential equations and partial differential equations; Problem solving related to Aerospace Engineering using software tools.

Sl. No.	Name of the Experiment	No. of classes
1.	Introduction to Matlab and Simulink	3
2.	Introduction to LabVIEW and Solid works	3
3.	Introduction to C programming and Graphics	3
4.	Modeling and simulation of deflection of beam under different loading condition	3
5.	Simulation of motion of free fall with air resistance (parachute)	3
6.	Model and simulate the motion of crank-connecting rod and four bar mechanism	3
7.	Forward kinematics, inverse kinematics and dynamics of a two-link planner system	3
8.	Modeling the motion characteristics of spring-mass-damper (over-damped, under-damped and critically damped) system	3
9.	Solution of second order differential equation (ODE) for servo motor control	3
10.	Moving object detection and tracking	3
11.	Dynamics of bouncing ball in Virtual Reality environment	3
12.	Modeling, simulation and analyzing tools in Aerospace Engineering	3
13.	End Test and viva examination	3
		Total class: 39

Course Outcomes:
Upon completing this course, students will be able to:

- Students will be able to apply mathematical concepts to real-world problems, build and analyse models, and use simulations to understand complex engineering systems involving interdisciplinary knowledge.
- They will develop analytical skills for problem solving using mathematical tools. Students will have a deeper understanding of the engineering system being modelled and will be able to make informed decisions based on the simulation results and data analysis.
- By seeing the "how" and "why" unfold, students gain a clearer understanding and replicate the process with greater confidence.

5th SEMESTER SYLLABUS

B. TECH
IN
AEROSPACE ENGINEERING

Low Speed Aerodynamics (AE 3101)
(Only for AE)

Contact Period : 4L per week **Full Marks : 100 [Credit – 04]**
Prerequisite : Elementary knowledge of Fluid Mechanics

Sl No.	Article	No. of Classes
1	**Equations in Ideal flow:** Rotational and Irrotational flow; velocity potential, Circulation and vorticity, vortex tube, Kelvin's circulation theorem, Stokes' Integral Theorem; Generalised Bernoulli's equation.	6
2	**Applications:** Examples of 2D potential flow, Laplace equation and principle of superposition, flow around a non-lifting cylinder, lifting cylinder, Complex Potential Function and Conformal mapping, Solution of 2D potential flow problems using complex analysis, Flow with Circulation; Kutta–Joukowski theorem; The Joukowski transformation and Joukowski airfoils; Vortex Motion.	12
3	**Incompressible flow over airfoils and finite wings:** Classical Aerofoil Theory – Camber and Thickness Problems; Downwash and induced drag, Biot-savart law and Helmholtz's theorems; Prandtl's lifting line theory; Lifting surface theory.	14
4	**Computational methods:** Source and Vortex Panel Methods.Vortex lattice method; 3D source and Doublet; Algorithm and development of panel method code.	10
5	**Wind Tunnel Testing:** Classification and types; special problems of testing; Layouts; sizing and design parameters, Model mount, Model fabrication, Forces/moments measurements and balance calibration, Pressure measurements - Pressure scanners and data acquisition, Multi-holes probes, Velocity measurements – Pitot tube, Hot wire anemometry, laser techniques, Particle Image Velocimetry (PIV); visualization techniques - smoke, Tufts, Pressure sensitive paint, laser sheet, and surface oil flow.	10
	Total	**52**

Course Outcomes:
Upon completing this course, students will be able to:

- Understanding and implementation of the analysis of inviscid incompressible flows and the application of these to the flow over airfoils and finite wings.
- Computationally implement Source and Vortex Panel Methods, Vortex lattice method, 3D source and Doublet.
- Thorough understanding of wind tunnels and wind tunnel tests and associated measurement techniques for the measurement of aerodynamic moments, lift, drag, pressure and the velocity distribution and thereby develop the ability to apply these in wind tunnel testing.

Books recommended:

1. J D Anderson, Jr., *Fundamentals ofAerodynamics,* McGraw-Hill International
2. E L Houghton and A E Brock, *Aerodynamics for Engineering Students*, Edward Arnold
3. E L Houghton and N B Carpenter, *Aerodynamics for Engineering Students*, Edward Arnold
4. J Katz and A E Plotkin, *Low Speed Aerodynamics,* Cambridge University Press
5. Rae, W.H. and Pope, A., "Low Speed Wind Tunnel Testing", John Wiley Publication, 1984.

Aircraft Stability and Control (AE 3102)
(Only for AE)

Contact Period : 4L Per Week **Full Marks : 100 [Credit – 04]**
Prerequisite : Static Stability of Aircraft

Sl No.	Article	No. of Classes
1.	**Introduction:** Basic Terminologies of Control System; Transfer Function; Block Diagram; Open Loop and Closed Loop Transfer Function; State Space Analysis; procedural steps for solving physical systems through state variable approach; State Transition Matrix; Relationship between Transfer Function and State Space Equation	08
2.	**Stability:** Introduction; The Characteristics Equation; The Routh-Hurwitz Stability Criterion; Time Domain Analysis; Frequency Response; Stability and relative stability using Root Locus approach; Bode Plot; Nyquist Stability Criterion	10
3.	**PID Controllers:** Response of First Order and Second Order Systems with Proportional (P), Derivative (D), Integral (I), PD, PI, PID Control	04
4.	**Optimal Control Design:** Linear Quadratic Regulator (LQR) Design	04
5.	**Linearised Longitudinal Dynamics:** Fundamentals of Dynamics – Eigenvalue Problems; Longitudinal Motion: The Linearised Coupled Equations; Short Period Approximation; Long Period Approximation; Pure Pitching Motion	06
6.	**Linearised Lateral dynamics:** Lateral Motion – The Linearised Coupled Equations; Roll Approximation; Spiral Approximation; Dutch Roll Approximation; Pure Rolling Motion; Pure Yawing Motion; Longitudinal-Lateral Coupling; Nonlinear Effects	10
7.	**Flying and Handling Qualities:** Introduction; Short Term Dynamic Models; Flying Qualities Requirements; Aircraft Role; Longitudinal Flying Qualities Requirements; Control Anticipation Parameter; Lateral Directional Flying Qualities Requirements; Flying Qualities Requirements on the s-Plane	04
8.	**Stability Augmentation:** Introduction; Augmentation System Design; Closed Loop System Analysis; The Root Locus Plot; Longitudinal Stability Augmentation; Lateral-directional Stability Augmentation; The Pole Placement Method.	06
	Total	**52**

Course Outcomes:
Upon completing this course, students will be able to:

- This course will also help in creating a background to design an airplane from stability and control aspects. Students will be able to describe and analyze aircraft stability and control, understand the contributions of various components to stability, and apply their knowledge to design and analyze control systems for aircraft. Students will be able to use software like MATLAB to generate and analyze control-system designs.

Books:

1. Flight Stability and Automatic Control *by* Robert Nelson, McGraw Hill 2nd Edition
2. Aircraft Dynamics from Modeling to Simulation *by* Marcello R. Napolitano,John Wiley & Sons, Inc.
3. Aircraft Flight Dynamics and Automatic Flight Control *by* Part I & Part II by Jan Roskam, Darcorporation; Reprint edition (January 2001).
4. Mechanics of flight *by* Phillips,W.R. .2nd Edition John Wiley 2010.
5. Flight Dynamics Principles *by* M.V.Cook, John Wiley & Sons Inc.
6. Modern Control Engineering by Katsuhiko Ogata.
7. N. S. Nise: Control Systems Engineering, 4th Ed., Wiley, 2004.

Numerical Methods and Computational Tools (AE 3103)

(Only for AE)

Contact Period : 3L per week **Full Marks : 100 [Credit – 03]**
Prerequisite : Elementary knowledge of mathematics

Sl.	Article	No. of classes
1.	**Solution for linear systems of equation:** Elementary definitions related to matrix operation – matrix norm – consistency of the system – stability of the system – diagonal dominance & positive definiteness – direct methods of solution (inversion, Gauss method with normal & partial pivoting, Gauss-Jordan method, LU decomposition, Cholesky decomposition) – iterative methods and convergence study (Gauss-Siedel, Jacobi) – application to physical systems and development of codes using MATLAB Solution for nonlinear system of equations: Newton's vector method	09
2.	**Eigen values and eigen vectors**: Characteristic polynomials – eigen pair – power method, inverse power method, shifted inverse power method – application to physical systems and development of codes using MATLAB	04
3.	**Numerical differentiation**: Approximation of derivatives (forward, backward, central) – error analysis – numerical difference formulae	04
4.	**Numerical integration**: Closed Newton-Cotes quadrature – composite and recursive rule – error analysis – adaptive quadrature – Gaussian quadrature	04
5.	**Solution to ODE:** Initial value problem using various approaches (Taylor, Picard, Euler, Heun, 4th Runge-Kutta, Predictor-Corrector) – error analysis – system of differential equations – higher order differentia l equations. Boundary value problems – application to physical systems and development of codes using MATLAB	04
6.	**Solution to PDE:** Equation classification – solution using finite difference analogue – Jacobi & Gauss-Siedel approach for elliptic PDE – explicit (Bender-Schmidt) & implicit (Crank-Nicholson) approach for parabolic PDE – implicit & explocit approach for hyperbolic PDE – application to physical systems and development of codes using MATLAB	06
7.	**Introduction to computational tool :** Definition – DOF, nodes, element – direct stiffness method – natural and geometric boundary condition – element characteristic matrix – derivation of element stiffness matrix for bar and beam element – element assembly – several approaches for imposing boundary conditions – briefing on bandwidth, node numbering, matrix sparsity etc. – hand computation of several problems of basic level.	08
	Total	39

Course Outcomes:

Upon completing this course, students will be able to:

- This course creates a strong background regarding conversion of analytical approach to an equivalent numerical framework. Numerical approach is very much essential to study the other aerospace subjects in the current as well as in the higher semester. Proper study of this course will surely be beneficial for the students to write computer program properly and efficiently.

Books recommended:

1. Numerical methods using MATLAB, Mathews & Fink, PHI
2. Introductory methods of numerical analysis, Sastry, PHI
3. Concepts and applications of finite element analysis, Cook et al., John Wiley & Sons

Aircraft Dynamics and Navigation (AE 3104)

(Only For AE)

Contact Period : 4L per week **Full Marks : 100 [Credit – 04]**

Sl No.	Article	No. of Classes
1	**Introduction:** Aircraft coordinate system, definition of angle of attack, sideslip angles	4
2	**Newton's Second Law for Rigid Body Dynamics:** Derivation of forces and moments for a rigid body, Inertia tensor of aircraft, Application of simplified 6dof equations for basic flight maneuvers	8
3	**Position and Orientation:** Frame of reference, Euler angles, Transformation matrices for body frame to earth fixed frame and vice versa	9
4	**Aircraft equations of motion:** Linearized Equations of Motion, Aerodynamic force and moment representation, Stability derivatives, Transformation of Stability Axes	13
5	**Inertial and Gyroscopic Coupling:** Historical background, Simplified 5 dof model for inertia coupling, roll divergence, gyroscopic effect of propeller, engines	6
6	**Navigation:** Introduction to Navigation – types of navigation and their historical emergence; Navigation tools – some useful navigation conventions and mathematics; Inertial Navigation – inertial frame concept, Einstein box experiment, navigation formulation, shape of earth, gravitation and gravity, WGS-84, ECI-frame and LPI-frame; Instrumenting Inertial Navigation – property of gyro and accelerometer, gimbaled inertial navigation mechanization; Strapdown Inertial Navigation – coordinate transformation schemes, rate equations involving Euler angles, direction cosines and quaternions, strapdown inertial navigation mechanization; Non inertial navigation frame - navigation in rotating earth frame, local vertical and geographic frames; Alignment – static self alignment principle involving gimbaled navigation and strapdown navigation; Satellite Based Navigation – principle of position determination, geometric range and pseudo range, GPS scheme description, concept of GDOP, error characteristics and comparison between SNS and INS	12
Total		52

Course Outcomes:

Upon completing this course, students will be able to:

- Students will be able to derive and apply the equations of motion for aircraft, including the longitudinal and lateral-directional dynamics.
- Students will be able to design and analyze aircraft navigation systems, including GPS, INS, and other navigation aids.
- Students will be able to predict aircraft behavior in various flight regimes, including steady-state and dynamic conditions.
- Students will be able to apply navigation principles to real-world problems, including route planning and navigation system design.

- Students will be able to evaluate the performance of navigation systems, including accuracy, integrity, and availability.
- By achieving these course outcomes, students will gain a comprehensive understanding of aircraft dynamics and navigation principles, preparing them for careers in aircraft design, navigation system development, and aviation.

<u>Books recommended</u>:

1. W. F. Philips, Mechanics of Flight – Willey India
2. Nelson, Flight Mechanics an Automatic control –Tata McGrawHils
3. Richard E. , Coupling Dynamics in Aircraft: A Historical Perspective- DayDryden Flight Research CenterEdwards, California
4. Aerospace Navigation Systems - Alexander V. Nebylov, Joseph Watson, Wiley

Composite and Structures (AE 3105)
(Only for AE)

Contact Period : 3L per week **Full Marks : 100 [Credit – 03]**
Pre-requisite : Preliminary knowledge of strength of materials

Sl No.	Article	No. of Classes
1	Introduction to composite materials: Definitions; constituent materials; terminologies; general characteristics; advantages and uses.	03
2	Manufacturing processes of composite materials: Contact moulding methods; compression moulding methods and filament winding.	03
3	Micromechanical analysis of composite strength and stiffness: Volume and weight fractions; longitudinal strength and stiffness; transverse modulus; inplane shear modulus and Poisson's ratio.	06
4	Elastic properties of unidirectional lamina: stress-strain relationship; engineering constants; transformation of stress and strain; transformation of elastic constants; transformation of engineering constants.	10
5	Analysis of laminated composites: strain-displacement relationship; stress-strain relations; equilibrium equations; laminate stiffness; determination of lamina stresses and strains; types of laminate configurations.	11
6	Failure theories and strength of a unidirectional lamina: Micromechanics of failure of unidirectional lamina; anisotropic strength and failure theories.	06
Total		**39**

Course Outcomes:
Upon completing this course, students will be able to:
- Familiar with different types of manufacturing processes of components made of composite materials
- Able to design and develop different structural parts made of composite materials
- Capable to do failure analysis of FRP structures after completion of this course

Books recommended :

1. Madhujit Mukhopadhyay, Mechanics of Composite Materials and Structures, Universities Press, 2004.
2. R. M. Jones, Mechanics of Composite Materials, McGraw Hill, 1993.
3. T. H. G. Megson, Aircraft Structures for Engineering Students, Butterworth Heinemann, 4th Ed., 2007

Low Speed Aerodynamics Laboratory (AE 3171)

(Only for AE)

Contact Period: 0L-0T-3P per week **Full Marks: 50 [Credit – 02]**

Sl. No.	Name of Experiments	No of classes
1	Introduction	03
2	Characteristics of a wind tunnel	03
3	Experiments to study separation process and associated stall characteristics with respect to different airfoils	03
4	Calibration of pitot tube with electronic differential pressure sensor and sample data acquisition	03
5	Calibration of a cup anemometer with sample data acquisition	03
6	Measurement of a fixed pitch propeller characteristics at hover	03
7	Measurement of dynamic characteristics of a fixed pitch propeller	06
8	Flow visualisation using water tunnel	03
9	Makeup classes	06
Viva voce		03
Total		**39**

Course Outcomes:

Upon completing this course, students will be able to:

- Students will be able to explain the basics of aerodynamics, including Bernoulli's principle, lift and drag forces, and airfoil characteristics.
- Students will be able to design and conduct experiments to measure aerodynamic forces and moments on airfoils and wings.
- Students will be able to analyze and interpret experimental data, and compare with theoretical predictions.
- Students will be able to demonstrate an understanding of the effects of Reynolds number, angle of attack, and cambered airfoils on aerodynamic performance.
- Students will be able to effectively communicate their results through written reports and presentations.
- The experiments are updated by student projects who learn to design and develop hardware and software for data acquisition.
- By achieving these course outcomes, students will gain a solid understanding of low-speed aerodynamics and develop practical skills in experimental techniques, data analysis, and reporting.

Aircraft Stability and Control Laboratory (AE 3172)

(Only for AE)

Contact Period: 0L-0T-3P per week **Full Marks: 50 [Credit – 02]**
Prerequisite:

Sl No.	Name of experiments	No. of Classes
1	Introduction to MATLAB for Control System Engineering	02
2	**SRV02:** A. SRV02 Modeling:Deriving the dynamic equation and transfer function for SRV02 servo plant using the first-principles B. Frequency Response Experiment C. Experiment with Step Input D. Model Validation Experiment	03
3	**SRV02 Position Control Experiment**	03
4	**SRV02 Speed Control Experiment**	03
5	**Rotary Pendulum: Modeling and Experiment** A. Experiment with Balance Control B. Experiment with Swing-up Control	03
6	**Rotary Double Inverted Pendulum:** Modeling,Simulation and Experiment	03
7	**Rotary Flexible Link:** Modeling,Simulation and Experiment	03
8	**Experiment with Rotary Gyroscope**	03
9	**Experiment with Aero-2DOF Dual Rotor System:** Simulation and Experiment with A. PD Control B. State Feedback Control with LQRand Kalman Filter	06
10	**Experiment with Half-Quadrotor:** Simulation and Experiment with A. PD Control B. State Feedback Control with LQRand Kalman Filter	06
11	**An Exposure to LABVIEW Software for Solving the above Experimentin Real-Time**	01
	End Test and Viva voce	03
	Total	**39**

Course Outcomes:
Upon completing this course, students will be able to:

- Students develop a strong practical understanding of the stability and control principles of airplanes.
- Students develop valuable skills in problem-solving, critical thinking, and teamwork.

Books recommended:

1. Ogata, K., Modern Control Engineering, 4th Ed. Prentice Hall India, 2006.
2. User Manuals of the various experimental setups

Numerical Methods and Computational Tools Laboratory (AE 3173)

(Only for AE)

Contact Period: 0L-0T-3P per week **Full Marks: 50 [Credit – 02]**

Sl No.	Name of experiments	No. of Classes
1	Coding practice using different programming languages, like C / C++ etc. on different numerical methods that includes (i) Solution for linear and non-linear systems of equation (ii) Eigen values and eigen vectors (iii) Numerical differentiation and integration (iv) Solution to ODE and PDE.	33
	Viva voce	06
	Total	**39**

Course Outcomes:

Upon completing this course, students will be able to:

- Students will be able to confidently implement numerical methods in solving different engineering problems and the developed skill will be useful for computational aerodynamics and structural analysis in higher semesters. Students will be able to apply numerical methods to real-world problems in various disciplines.

6th SEMESTER SYLLABUS

B. TECH
IN
AEROSPACE ENGINEERING

High Speed Aerodynamics (AE 3201)
(Only for AE)

Contact Period: 4L per week **Full Marks : 100 [Credit – 04]**
Prerequisite: Elementary knowledge of low speed aerodynamics, Engineering thermodynamics

Sl No.	Article	No. of Classes
1	**One Dimensional Flow:** One Dimensional Flow revisited; Hugoniot Equations; One Dimensional Flow with Heat Transfer; One Dimensional Flow with Friction. Problems.	04
2	**Two Dimensional Flow:** Two Dimensional Flow revisited; Shock Polar; Shock Reflection and Intersection; Bow Shock in front of a Blunt Body; Three Dimensional Shock Waves; Prandtl-Meyer Expansion Waves; Shock-Expansion Theory. Problems.	08
3	**Quasi-One Dimensional Flow:** Quasi-One Dimensional Flow revisited; Nozzles; Diffusers. Problems.	06
4	**Unsteady Wave Motion:** Introduction; Moving Normal Shock Waves; Reflected Shock Waves; Elements of Acoustic Theory; Finite Waves; Incident and Reflected Expansion Waves; Shock tube Relations; Finite Compression Waves.	10
5	**Linearised Flow:** Introduction; Differential Conservation equations for Inviscid Flow; Crocco's Theorem; Velocity Potential Equation: Linearised Velocity Potential Equation; Linearised Subsonic Flow; Linearised Supersonic Flow; Method of Characteristics.	10
6	**Three Dimensional Flow:** Cones at Angle of Attack; Blunt Bodies at Angle of attack.	06
7	**Numerical Techniques**: Steady and Unsteady Supersonic Flow	08
	Total	**52**

Course Outcomes:
Upon completing this course, students will be able to:
- Students will be able to explain the principles of compressible flow physics and shock dynamics.
- Students will be able to apply their knowledge to design and analyze different internal flows like nozzle, aircraft engine duct as well as over external aerodynamics of supersonic vehicles.

Books recommended :

1. J. D. Anderson Jr., Modern Compressible Flow with Historical Perspective, McGraw Hill
2. A H Shapiro, Dynamics and Thermodynamics of Compressible Fluid Flow-Volume I& II, Ronald Press
3. H W Liepmann and A Roshko,Elements of Gas Dynamics, John Wiley & Sons

Theory of Propulsion (AE 3202)
(Only for AE)

Contact Period: 4L per week **Full Marks: 100 [Credit – 04]**
Prerequisite: Knowledge of all subjects of previous semesters

Sl No.	Article	No. of Classes
1.	**Component Performance:** Introduction; Variation of Gas Properties; Component Performance; Inlet and Diffuser Pressure Recovery; Compressor and Turbine Efficiencies; Burner Efficiency and Pressure Loss; Exit Nozzle Loss.	08
2.	**Parametric Cycle Analysis of Real Engines:** Introduction; Turbojet; Turbojet with Afterburner; Turbofan – Separate Exhaust System; Turbofan with Afterburning - Separate Exhaust System; Turbofan with Afterburning - Mixed Exhaust Stream; Turboprop Engine; Variable Gas Properties.	12
3.	**Engine Performance Analysis:** Introduction; Gas Generator; Turbojet Engine; Turbojet with Afterburning; Turbofan Engine - Separate Exhausts and Convergent Nozzles; Turbofan with Afterburning – Mixed-Flow Exhaust Steam; Turboprop Engine; Variable Gas Properties.	12
4.	**Turbomachinery:** Introduction; Euler's Turbomachinery Equations; Axial Flow Compressor Analysis; Centrifugal-Flow Compressor Analysis; Axial Flow Turbine Analysis; Centrifugal-Flow Turbine Analysis.	10
5.	**Inlets, Nozzles and Combustion systems:** Introduction to Inlets and Nozzles; Inlets; Subsonic and Supersonic Inlets; Exhaust Nozzles; Introduction to Combustion systems; Main and after Burners.	10
	Total	**52**

Course Outcomes:
Upon completing this course, students will be able to:
- Students can design different components of aircraft engines like diffusers, nozzles, and combustion chambers for different flight conditions.
- Students can calculate thrust and efficiencies of different aircraft engines using given flight conditions.
- Students can analyze brayton cycle, and can calculate thermal efficiency and work ratio for modified brayton cycle.
- Students are able to draw velocity triangles for turbines and compressors, and can analyze blade design.

Books:
1. J. D. Mattingley, Elements of Gas Turbine Propulsion, Tata McGraw Hill

Aerospace Structures (AE 3203)
(Only for AE)

Contact Period: 4L per week **Full Marks: 100 [Credit – 04]**
Prerequisite: Advanced Strength of Materials

Sl No.	Article	No. of Classes
1.	**Flight Vehicle Structures and Materials:** Structural components of aircraft and their functions – structural idealization – aircraft materials – strength-weight comparisons of materials – theories of failures – Airy stress function and its applications	12
2.	**Airframe Loads:** Airworthiness requirements – load factors – limit loads – ultimate loads – reserve factor and margin of safety – basic flight loading conditions – V-n diagram – fail-safe and safe-life approach – aircraft fatigue life – inertia loads analysis – analysis of manoeuvre loads (including acceleration) – analysis of gust loads	14
3	**Analysis of Open & Closed Section Beam:** Unsymmetrical bending – bending approximation for thin walled section – stress-strain-displacement relation for open & closed thin walled beam – shear flow, shear center & applications – shear of open section beam – shear of closed section beam – torsion of closed section beam – torsion of open section beam using membrane analogy – analysis of combined open & closed section – deflection of open & closed section beams	18
4.	**Stress Analysis of Aircraft Components:** Fuselage and wing ribs – cut-outs in semi-monocoque structures – joints and fittings	8
	Total	**52**

Course Outcomes:
Upon completing this course, students will be able to:

- Grasp the fundamental behavior of symmetrical and unsymmetrical thin-walled aircraft components under bending and shear loading and understand the concepts of shear flow and shear center.
- Evaluate torsional warping and shear stresses in both closed and open sections.
- Apply the concept of structural idealization for stress analysis of open and closed section beams, including single and multi-cell configurations.
- Evaluate inertia load, airframe load under steady flight condition and gust load condition.

Books recommended:
1. Aircraft Structures for Engineering Students – T.H.G. Megson
2. Aircraft Structures – David J. Peery
3. Analysis and Design of Flight Structures – E.F. Bruhn
4. Airframe Stress Analysis and Sizing – Michael C. Y. Niu
5. The Aeroplane Structure – A. C. Kermode
6. Elasticity in Engineering – E.E. Sechler

Introduction to FEM and Applications (AE 3204)

(Only for AE)

Contact Period : 4L per week **Full Marks : 100 [Credit – 04]**
Prerequisites : Advanced Strength of Materials, Numerical Method and Computational Tools

Sl.	Article	No. of classes
1	Variational (Rayleigh-Ritz) approach – Pascal's triangle – strong and weak form of formulation – natural coordinates and shape functions for different cases – isoparametric, subparametric and superparametric element – bar,beam,frame, quadratic plane, hexahedral element, plane stress element – patch test	16
2	Coordinate transformation – stress, strain, material properties, stiffness matrices	08
3	Basic aspects of plate bending – governing differential equations – various boundary conditions – various classical solutions – application of FEM in Kirchhoff and Mindlin theory	14
4	Weighted residual (Collocation, Least Square, Sub-domain collocation, Galerkin) approach – derivation of basic equation using classical & FE form – example solution	10
5	Comparison of FEM with other computational methods	04
	Total	**52**

Course Outcomes:
Upon completing this course, students will be able to:

- Proper knowledge of FEM and related applications will strengthen students regarding the idealization and solving aircraft structural real-life problems.

Books recommended:

1. Numerical methods using MATLAB, Mathews & Fink, PHI
2. Introductory methods of numerical analysis, Sastry, PHI
3. Concepts and applications of finite element analysis, Cook et al., John Wiley & Sons

Orbital Mechanics (AE 3205)
(Only for AE)

Contact Period: 4L per week **Full Marks : 100 [Credit – 04]**
Prerequisite: Physics, Dynamics and Mathematics

Sl.	Article	No. of classes
1.	**Two Body Problem:** Introduction; Equation of Motion in an Inertial frame; Equations of Relative Motion; The Orbit Formulas; Energy Law; Different Orbits and Trajectories, Perifocal Frame; The Lagrange Co-efficient.	12
2.	**Orbital Position as a Function of Time:** Introduction; Time since Periapsis; Applications to different Orbits and Trajectories.	07
3.	**Orbits in Three Dimensions:** Introduction; Geocentric Frames; Orbital Elements and State Vectors, Coordinate Transformation; Application between Geocentric Frames, Effect of Earth's Oblateness; Ground Tracks.	09
4.	**Preliminary Orbit Determination:** Introduction; Gibbs Method for Orbit Determination; Lambert's Problem; Sidereal Time; Different Topocentric Coordinate Systems; Orbit Determination.	10
5.	**Orbital Maneuvers:** Introduction; Impulsive Maneuvers; Hohmann Transfer; Phasing Maneuvers; Hohmann Transfers; Apse Line Rotation; Chase Maneuvers; Phase Change Maneuvers; Nonimpulsive Orbital Maneuvers.	14
	Total	**52**

Course Outcomes:
Upon completing this course, students will be able to:
- Students will be able to determine the type of orbits
- Acquire basic ideas about different types of frames used in space mechanics
- Able to keep track of a satellite and have knowledge of different types of orbit maneuvers
- May take part in launch programs of satellites in an orbit and interplanetary mission.

Books:
1. H. D. Curtis, Orbital Mechanics for Engineering Students, B. H., Elsevier

High Speed Aerodynamics Laboratory (AE 3271)

(Only for AE)

Contact Period: 0L-0T-3P **Full Marks : 50 [Credit – 02]**

Sl No.	Name of experiments	No. of Classes
1	Nozzle Choking Testing, Nozzle Pressure Distribution and Nozzle Performance Testing	33
	Viva Voce	06
	Total	**39**

Course Outcomes:
Upon completing this course, students will be able to:

- Students get an idea over nozzle choking which can be very useful for the nozzle flows in rocketry and aircraft. They can learn to measure the free stream Mach number inside the test section of a manually operated hypersonic shock tunnel.

PROPULSION LABORATORY (AE 3272)

Contact Period: 0L-0T-3P **Full Marks: 50 [Credit – 02]**

	Name of Experiments:	No. of Classes
1	Performance studies of lab-scale subsonic ramjet engine, Propeller blade theory and measurement of propeller lift force, Performance studies of a duct burner, Laminar flame speed studies in a hollow cylindrical pipe, Flame characterization studies: Diffusion to premixed flame using flame stabilization set-up, Torque measurement studies over a reaction turbine,	33
	Viva Voce	06
	Total	**39**

Course Outcomes:
Upon completing this course, students will be able to:

- Students can calculate thrust and thermal efficiencies using experimental conditions.
- Students can calculate stoichiometric conditions for air/fuel combustion.
- Students can calculate the figure of merit for propeller engines.

Aircraft Design and Flight Training (AE 3273)

(Only for AE)

Contact Period: 0L-0T-3S per week **Full Marks: 50 [Credit – 02]**

Sl No.	Name of experiments	No. of Classes
1.	Introduction	02
2.	Different Phases of Design	02
3.	Starting with an Example – a very rudimentary design	10
4.	Selection of an Airfoil	05
5.	Flight Training (Two weeks long course at IIT Kanpur)	20
	Viva voce	
	Total	**39**

Course Outcomes:

Upon completing this course, students will be able to:

- *Design and analyze aircraft configurations*: Students will be able to apply basic sizing and conceptual design principles to create feasible aircraft designs.
- *Operate and handle aircraft*: Students will gain practical experience in flight training, learning to safely operate and handle aircraft.
- *Collect and analyze flight data*: Students will learn to collect and analyze in-flight data, gaining insights into aircraft performance and behavior.
- *Interpret log analysis results*: Students will be able to analyze flight logs, identifying trends and areas for improvement.
- *Apply theoretical knowledge to real-world scenarios*: Students will develop a deeper understanding of aircraft design and performance, applying theoretical concepts to practical problems.
- Students will be able to create conceptual sketches of aircraft designs, considering factors such as aerodynamics, structures, and performance.
- Students will be able to conduct basic sizing calculations for aircraft design, including weight estimation, wing area calculation, and thrust-to-weight ratio analysis.
- Students will demonstrate proficiency in flight training, showcasing safe and efficient aircraft handling skills.
- Students will be able to collect and analyze flight data, including parameters such as altitude, airspeed, and control surface deflections.
- Students will be able to interpret log analysis results, identifying trends and areas for improvement in aircraft performance and opeations.
- By achieving these course outcomes, students will gain a comprehensive understanding of aircraft design and flight training, preparing them for careers in the aerospace industry.

7th SEMESTER SYLLABUS

B. TECH
IN
AEROSPACE ENGINEERING

Computational Fluid Dynamics (AE 4101)
(Only for AE)

Contact Period : 4L per week **Full Marks : 100 [Credit – 04]**
Prerequisite : Aerodynamics, Numerical Mathematics
Course objective: This course is intended to give students an exposure to different methods to solve various differential equations used to describe fluid flow phenomenon.

Sl No.	Article	No. of Classes
1	**Introduction**	02
2	**Basics of Discretisation Methods:** Difference Representations; Errors; Consistency; Stability; Convergence	04
3	**Applications of Numerical Methods to Selected Model Equations:** Wave Equation; Heat Equation; Laplace's Equation; Burger's Equations	10
4	**Governing Equations of Fluid Mechanics:** Fundamental equations; Averaged Equations of Turbulent Flows; Boundary layer Equations; Introduction to Turbulence Modelling; Euler Equations; Transformation of Governing Equations	10
5	**Finite-Volume Formulation:** Two-Dimensional Finite Volume Methods; Three-Dimensional Finite Volume Methods	10
6	**Numerical Method Applications:** Euler Equations; Boundary layer Equations; Parabolised Navier Stokes equations; Navier-Stokes equations; Grid Generations	10
7	**Compressible flow- Density based solver**	06
	Total	**52**

Contribution of course to meeting the Professional component: The students can use this knowledge and training not only in their further academic pursuance but also in different industrial applications.

Course Outcomes:
Upon completing this course, students will be able to:

- Students learn geometrical and mathematical modelling by formulating governing equations with proper boundary conditions using CFD and comparing CFD results with experimental and analytical results (if available). Understand practical aspects of computational modelling of flow domains and grid generation. Students will be familiar with different methods- FDM, FVM through this course. They are also able to apply CFD techniques to solve real-world engineering problems.

Books recommended :

1. Computational Fluid Mechanics and Heat Transfer: J. C. Tennehill, D. A. Anderson, R. H. Pletcher; Taylor and Francis
2. Introduction to Computational Fluid Dynamics: Pradip Niyogi, S. K. Chakrabartty, M. K. Laha; Pearson Education
3. Computational Fluid Dynamics – The Basics with Applications: J. D. Anderson Jr.; McGrawHill

Jet and Rocket Propulsion (AE 4102)
(Only for AE)

Contact Period: 3L per week **Full Marks : 100 [Credit – 03]**
Prerequisite: Thermodynamics, Fundamentals of Fluid Mechanics, Compressible flow, Theory of propulsion

Sl No.	Article	No. of Classes
1.	**Introduction:** Brief history of rocketry, classification of rocket propulsion systems	02
2.	**Ideal Rocket Nozzle Performance:** Rocket nozzle design and its performance.	04
3.	**Theory of Rocket Propulsion:** Rocket principle and rocket equation, desirable parameters of a rocket, propulsive efficiency of rocket, multistage and clustering of rockets.	10
4.	**Chemical Propellants:** Combustion and Thermochemistry	04
5.	**Solid Rocket Motors:** Mechanism of burning, evaluation of burn rate, propellant grain configuration	07
6.	**Liquid Rocket Engines:** General description, engine cycles, propellant feed system, component design fundamentals, progress of combustion in combustion chamber and nozzle, liquid droplet vapourization, mixing and chemical reaction	08
7.	**Electric Propulsion:** Classification of electric propulsion systems, performance analysis	04
Total		**39**

Course Outcomes:
Upon completing this course, students will be able to:

- Explain the fundamental principles of jet and rocket propulsion systems based on thermodynamics, fluid mechanics, and gas dynamics.
- Analyze the performance parameters of jet engines and rocket propulsion systems, including thrust, specific impulse, efficiency, and fuel consumption.
- Apply compressible flow theory to study nozzle flows, shock waves, and expansion in propulsion systems.
- Explain the principles of staging, orbital mechanics, and trajectory optimization in rocket propulsion applications.

Books recommended:

1. Rocket Propulsion by G. W. Sutton
2. Missile Aerodynamics by J. Nielsen
3. Mechanics and Thermodynamics of Propulsion, P. Hill and C. Peterson, Addison-Wesley Publishing Company.
4. Rocket and Spacecraft Propulsion, M. J. L. Turner, Springer Praxis Publishing.
5. Propulsion Techniques, P. J. Turchi, Ed., AIAA Book Series.
6. Introduction to Rocket Science and Engineering, Travis S. Taylor, CRC Press (Taylor and Francis Group).
7. Rocket Propulsion, Ramamurthy

Aerospace Structures Laboratory (AE 4171)

(Only for AE)

Contact Period : 0L-0T-3P per week **Full Marks : 50 [Credit – 02]**

Sl No.	Name of experiments	No. of Classes
1.	Introduction of Analog to Digital Converter (HDA200)	03
2.	Deflection of Frames – i) S – Frame, ii) Rectangular Portal Frame	06
3.	Buckling of Thin Struts	06
4.	Shear Centre of Different Thin walled Sections	09
5.	Reporting on experiments and necessary corrections	03
6	Bending Stresses in Beams	03
7.	Plastic Bending of Beams	03
8.	Two dimensional Bending	03
9.	Viva voce	03
	Total	39

Course Outcomes:

Upon completing this course, students will be able to:

- Experimentally determine the deflection of frames under applied loads.
- Analyze and interpret buckling behavior of slender struts and experimentally determine critical load
- Locate the shear center of open thin-walled sections and understand its significance in structural design.
- Demonstrate understanding of plastic deformation in beams
- Calculate bending stress distribution in a 'T' beam and validate it through practical testing.
- Develop competency in using lab equipment and experimental techniques for structural analysis.

Aircraft Design and Manufacturing Techniques (AE 4172)

(Only for AE)

Contact Period: 0L-0T-4S per week **Full Marks: 50 [Credit – 02]**

Sl. No.	Article	No. of Classes
1	**Design of wing:** Numerical modelling of a wing using Lifting line theory. Design of a flying wing	6
2	**Tail design:** Tail sizing from static and dynamic stability, spin recovery	6
3	**High lift devices:** Working principle of highlight devices, Types of Leading and trailing edge HLD, Aerodynamic characteristics. Selection of HLD	6
4	**Drag estimation:** Estimation of skinfriction drag, Estimation of drag of complete aircraft using CBBM method	6
5	**Propeller propulsion:** Propeller design usingBlade element theory (MATLAB implementation), Propeller selection from experimental data	6
6	**Design of landing gear:** Types, Stability analysis of various configurations of landing gear, Geometric designing of landing gear for any particular aircraft, Retraction of landing gear, mechanisms	6
7	**Computer Aided Manufacturing (CAM)**: CNC Technology and Programming, DNC, Adaptive Control	4
8	**Non-traditional Machining:** Principle and various processes- EDM, Wire EDM, ECM, AJM, LJM, Plazma Machining, Abrasive Water jet machining	4
9	**Industrial Automation:** Concept of CIM and FMS, Automated Material Handling, Assembly and Inspection, Computer Aided Process Planning, Group Technology and Cellular Manufacturing	4
10	**Additive Manufacturing:** 3D printing and 3D Scanner, Intelligent Manufacturing	4
		52

Course Outcomes:
Upon completing this course, students will be able to:

- Select the right airfoil, wings, sizing of propeller, motor, empanange sizing.
- overall application of aerodynamics, propulsion, flight mechanics into design of an aircraft.
- Analyze manufacturing constraints*: Students will be able to analyze manufacturing constraints and requirements, including producibility, inspectability, and maintainability.
- Evaluate aircraft design and manufacturing trade-offs: Students will be able to evaluate trade-offs between design requirements, manufacturing constraints, and production costs.
- understand cnc machine, gcode, elements of manufacturing in aircraft industry

- By achieving these course outcomes, students will gain a comprehensive understanding of aircraft design and manufacturing techniques, preparing them for careers in aircraft design, manufacturing, and engineering.

Books:

1. General Aviation Aircraft Design Applied Methods and Procedures – Snorr Gumundsson
2. The Design of the Aeroplane - Darrol Stinton
3. Aircraft Design: A Conceptual Approach - D. P Raymer
4. Airplane Design - Dr. J. Roskam
5. M. P. Groover - Fundamentals of Modern Manufacturing, Materials, Processes and Systems
6. P. C. Pandey and H. S. Shah - Modern Machining Processes
7. V. K. Jain - Advanced Machining Processes
8. M. P. Groover - Automation, Production Systems and Computer Integrated Manufacturing

Core Elective I (For 7th Semester)

Aerospace Structural Dynamics (AE 4121)
(Only for AE)

Contact Period : 3L per week **Full Marks : 100 [Credit – 03]**
Prerequisite : Theory of Vibration, Aerospace Structures

Sl No.	Article	No. of Classes
1	**Introduction and brief reviews of Aerospace Structures and Mechanical Vibration**	4
2	**Introduction to Calculus of Variation** Introduction, Functional, The First Variation, Euler-Lagrange Equation, Boundary Conditions	4
3	**Hamilton's Principle and Lagrange's Equation**	4
4.	**Development of a typical Aircraft Vibration Problem**	2
5.	**Beam Torsional Dynamics** Equation of Motion, General Solution, Boundary Conditions, Solution for mode shapes and frequencies.	7
	Beam Bending Dynamics Equation of Motion, Boundary Conditions, Solution for mode shapes and frequencies.	6
6.	**Approximate Solution Techniques in Structural Dynamics:** Rayleigh-Ritz Method, Galerkin's Method, Finite Element Method	8
7.	**String Dynamics:** Equation of Motion-Standing Wave Solution, Orthogonality of mode Shapes and its implication, Travelling wave solution.	4
	Total	**39**

Course Outcomes:
After successful completion, students will be

- Able to formulate basic vibration problems involving aerospace structural elements idealized as beams and bars
- Familiar with modal representation of beams in bending and torsion and solve related problems

Books recommended :

1. Introduction to Structural Dynamics and Aeroelasticity – D. H. Hodges and G. A. Pierce, Cambridge University Press
2. Elements of Vibration Analysis – L. Meirovitch, McGraw-Hill
3. Energy and Finite Element Methods in Structural Mechanics – I.H. Shames and C.L. Dym, CRC Press
4. Aeroelasticity – R.L. Bisplinghoff, H.Ashley and R.L.Halfman, Dover

Satellite Attitude Dynamics (AE 4122)
(Only for AE)

Contact Period : 3L per week **Full Marks : 100 [Credit – 03]**

Sl No.	Article	No. of Classes
1	Introduction; Kinematics, Equations; Moments of inertia; Euler Angles; Yaw, Pitch and Roll angles; Quaternions	14
2	Torque –free motion; Stability of Torque-free Motion; Dualspin Spacecraft; Nutation Damper; Conning Maneuver; Attitude Control Thrusters; Yo-yo Despin mechanism; Gyroscopic Attitude Control; Gravity Gradient Stabilisation	25
	Total	**39**

Book recommended:
1. Orbital Mechanics for Engineering Students H. D. Curtis

8th SEMESTER SYLLABUS

B. TECH
IN
AEROSPACE ENGINEERING

Turbulent Flow (AE 4201)
(Only for AE)

Contact Period : 4L per week **Full Marks : 100 [Credit – 04]**
Prerequisite: Knowledge of Partial differential equations, matrix algebra and elementary tensor algebra, fluid mechanics, viscous fluid flow

Sl No.	Article	No. of Classes
1.	**General introduction and concepts:** Factors affecting the transition to turbulent flow, classical experiments on the transition to turbulence, energy cascade, role of averaging in turbulent flow, averaging procedures, characteristics of turbulent flow, types of turbulent flow, Kolmogorov microscales of turbulence, other characteristic scales and orders of magnitude	06
2.	**Fundamental equations for turbulent flow:** Continuity equation for turbulent flow, Reynolds equation of motion, Reynolds stress and correlations, Correlation function, Statistical theory of turbulence, Fourier transform and spectra, Reynolds stress equation, Energy equation in a turbulent flow, Equation for dissipation of energy, Transfer of energy between mean flow and turbulence, Transfer of energy from mean flow to turbulence, Role of pressure.	14
3.	**Vorticity dynamics:** Vortex terms in the equation of motion, Reynolds stress and vortex stretching, The vorticity equation, Vortex line, Vortex tube, Vorticity in turbulent flows, The Enstrophy equation, The dynamics of $\overline{\omega_i \omega_i}$. The equation for $\overline{\omega_i' \omega_i'}$. Vorticity budget. Length scales.	08
4.	**Wall bounded turbulent flows:** Duct flow, balance of mean forces, near wall shear stress, mean velocity profile, turbulent kinetic energy budget, length scales and mixing length; Turbulent flow in duct; Turbulent flow over flat plate; Turbulent boundary layers, mean momentum equation, mean velocity profile, Reynolds stress balances	08
5.	**Turbulence modelling:** Phenomenological theories of turbulence, Boussinesq's theory, Prandtl's mixing length hypothesis, One equation models, Spalart Allmaras model, $k-\varepsilon$ model, $k-\omega$ model, Introduction to LES	10
6.	**Free shear turbulent flows:** Description of flow in a turbulent jet, self preservation, analysis of 2-D jet, Integral momentum equation, integral energy equation, entrainment hypothesis, scale relations.	06
Total		**52**

Course Outcomes:
After successful completion, students will be

- Students will become familiar with fundamental physics of turbulent flows.
- Students will become familiar with transport of moment, energy and vorticity in turbulent flows.

- Students will become familiar with the applications of turbulence in industry and environment.
- Students will be able to analyze simple shear, wall bounded and boundary layer flows with the use of phenomenological models of turbulence.
- Students will become familiar with different turbulence modelling techniques in the context of RANS based approaches
- Students will be familiar with LES equation and will have the background to implement LES

Books recommended:

1. Turbulence – P.A. Davidson, Oxford University Press
2. Turbulent flows – Stephen B. Pope, Cambridge University Press
3. A first course in turbulence – H. Tennekes and J. L. Lumley, M.I. T press

Core Elective II: (For 8th Semester)

Spacecraft Dynamics (AE 4221)
(Only for AE)

Contact Period: 3L per week **Full Marks: 100 [Credit – 03]**
Prerequisite: Aircraft Dynamics, Aerospace Vehicle Dynamics and Navigation

Sl No.	Article	No. of Classes
1	Satelite Attitude Dynamics: Introduction Torque Free Motion; Stability of Torque Free Motion; Dual Spin Spacecraft; Nutation Damper; Coning Maneuver; Attitude Control Thrusters; Yo-yo Spin Mechanisms; Gyroscopic attitude Control; Gravity Gradient Stabilisation.	03
2	Rocket Vehicle dynamics: Introduction; Equations of Motion; The Thrust Equation; Rocket Performance; Restricted Staging in Field Free Space; Optimal Staging.	04
3	Orbital Maneuvers: Introduction; Impulsive Maneuvers; Hohmann Transfer;Bi-elliptic Hohmann Transfer; Phasing Maneuvers; Non-Hohmann Transfers with Common Apse Line; Apse Line Rotation; Chase Maneuvers; Phase Change Maneuvers; Nonimpulsive Orbital Maneuvers.	08
4	Relative Motion and Rendezvous: Introduction; Relative Motion in Orbit; Linearisation of the Equations of Relative Motion in Orbit; Clohssy-Wiltshire Equations; Two-impulse Rendezvous maneuvers; Relative Motion in Close-proximity Circular Orbits.	08
5	Interplanetary Trajectories: Introduction; Interplanetary Hohmann Transfers; Rendezvous Opportunities; Sphere of Influence; Method of Patched Conics; Planetary Departure; Sensitivity Analysis; Planetary Rendezvous; Planetary Flyby; Planetary Ephimeris; Non-Hohmann Interplanetary Trajectories.	08
6	Introduction to Orbital Perturbations: Introduction; Cowell's Method; Encke's Method; Atmospheric Drag; Gravitational Perturbations; Variation of Parameters; Gauss Variational Equations; Method of Averaging; Solar Radiation Pressure; Lunar Gravity; Solar Garvity.	08
	Total	**39**

Books recommended:

Orbital Mechanics for Engineering Students by H. D. Curtis

Fracture Mechanics (AE 4222)
(Only for AE)

Contact Period: 3L per week **Full Marks: 100 [Credit – 03]**
Prerequisite: Mechanics of Solids**,** Numerical Methods, Finite Element Methods

Sl No.	Article	No. of Classes
1	Overview and Application of Fracture Mechanics Approach to Engineering Design, Effect of Material Properties on Fracture and Failure, Contributions of Inglis, Griffith and Irwin, Classification of LEFM and EPFM, Modes of Loading: Mode-I, Mode-II and Mode-III, Fracture Mechanisms: Brittle Fracture, Ductile Fracture, Fracture Mechanism in Metals and Non Metals, Void Nucleation and Growth, Ductile Brittle Transition.	06
2	Linear Elastic Fracture Mechanics (LEFM), Griffith Theory of Energy Balance, Energy Release Rate (G), Instability and R Curve, Stress Intensity Factor, (SIF) K, Relationship Between K and G, Crack-tip Stress and Displacement Field Equations, Westergaard Solution of Stress Field for Mode-I, Mode II, Mode III, SIF for Modeling of Plastic Deformation, Irwin's Model.	12
3	Elastic Plastic Fracture Mechanics (EPFM), Crack Tip Opening Displacement (CTOD), J Contour Integral, Relationship Between J and CTOD, J Controlled Fracture, Crack Growth Resistance Curves, HRR Field, Dynamic Fracture.	10
4	Fail-safe and Safe-life approach in Aircraft Design, Crack Initiation and Fatigue Crack Growth, Paris Law, Crack Closure.	04
5.	Fracture Toughness Testing on Metals.	02
6.	Fracture Mechanics using Finite Element Analysis.	05
	Total	**39**

Course Outcomes:
After successful completion, students will be

- Understand the fundamental concepts of fracture mechanics, including stress intensity factors and energy release rates.
- Analyze crack initiation and propagation using linear elastic and elastic-plastic fracture mechanics principles.
- Evaluate the fracture toughness of materials and apply failure criteria to structural components.
- Assess fatigue crack growth and predict component life under cyclic loading conditions.

Books recommended:
1. T.L. Anderson, Fracture Mechanics - Fundamentals and Applications, 3rd Edition, Taylor and Francis Group, 2005.
2. D. Broek, Elementary Engineering Fracture Mechanics, Kluwer Academic Publishers, Dordrecht, 4th revised Edition, 1982.
3. C.T. Sun, Z. –H. Jin, Fracture Mechanics, Academic Press, 2nd Edition, 2006.
4. Prashant Kumar, Elements of Fracture Mechanics, Tata McGraw Hill, New Delhi, India, 2009.

Aeroelasticity (AE 4223)
(Only for AE)

Contact Period: 3L per week **Full Marks: 100 [Credit – 03]**
Prerequisite: Variational Calculus, Hamilton's Principle and Lagrange's Equation, Aircraft Vibration Problem, Beam Torsional and Bending Dynamics, Approximate Solution Techniques in Structural Dynamics

Sl No.	Article	No. of Classes
1.	Introduction Overview and objectives; Classification and Solution of Aeroelastic problems; Aero-structure interaction; Deformation of Structures and Influence Coefficients;	7
2.	Static Aeroelasticity; Static stability of typical section; Divergence of airfoil and Finite Wing; Simple Aeroelastic Wind Tunnel Models; Aileron Reversal; Control Effectiveness; Wing Loading and Deformations; Swept wing static aeroelasticity-flexural axis concepts; Aeroelastic tailoring	12
3.	Dynamic Aeroelasticity; Stability Characteristics; 1D and 2D Flutter models; Standard Schemes of Flutter Analysis; Aerodynamic damping,; Modal coalescence	11
4.	Flutter calculation; U-g method; P-k method; Exact treatment of Bending-Torsion Flutter of Uniform Wing; Flutter Analysis by Assumed Mode method, Testing and models	9
	Total	**39**

Course Outcomes:
After successful completion, students will be able to

- Formulate and solve static aeroelasticity problems such as wing divergence and aileron reversal problems.
- Use simplified quasi-steady and unsteady aerodynamic theories and solve typical problems on binary flutter
- Develop a qualitative understanding of the role of aeroelastic phenomena in aircraft design and performance

Books recommended:
1. E.H. Dowell et al., "A Modern Course in Aero elasticity", Sijthoff & Noordhoff, 1980.
2. R.L. Bisplinghoff, H. Ashley and R.L. Halfman, "Aero elasticity", Addison-Wesley, 1955.
3. D.H. Hodges and G.A. Pierce, "Introduction to Structural Dynamics and Aeroelasticity" Cambridge Aerospace Series, 2002.
4. R.L. Bisplinghoff and H. Ashley, "Principles of Aeroelasticity", Dover, 1962.
5. R.H. Scanlan and R. Rosenbaum, "Introduction to the study of Aircraft Vibration and Flutter" Macmillan, 1951.
6. Y.C. Fung, "An Introduction to the Theory of Aeroelasticity", John Wiley & sons, 1955.
7. AGARD Manual on Aeroelasticity, Vol. I-VI, Since 1959 with continual updating.
8. H. Ashley, "Aeroelasticity", Applied Mechanics Reviews, Feb. 1970.
9. Blevins, R.D., Flow induced Vibrations, Von Nostrand Rheinhold co. 1977.

Fundamentals of Combustion in Propulsion (AE 4224)
(Only for AE)

Contact Period: 3L per week **Full Marks: 100 [Credit – 03]**
Prerequisite: Engineering Thermodynamics, Theory of Propulsion, Jet and Rocket Propulsion

Sl.	Article	No. of Lectures
1	**Introduction:** Introduction to combustion, Application of combustion, Fuel and oxidizer properties, Classification fuel and oxidizers used in propulsion, Various combustion modes, Scope of combustion in propulsion.	3
2	**Chemistry of Combustion:** Fundamentals of combustion kinetics, Elementary reactions, Chain reactions, Multistep reactions, simplification of reaction mechanism, Global kinetics.	4
3	**Laminar Premixed flame:** Physical description, Rankine-Hugonoit relations, Flame propagation and flame speed, Determination of flame speed, Factors effecting flame speed, Flame quenching and ignition, Limit phenomena – flammability limits, ignition, and flame stabilization. **Laminar Non-premixed flames:** Physical description, analysis of diffusion controlled systems, Shvab-Zeldovich Formulation, Analysis of typical laminar non-premixed flames, Partially premixed flames, Effect of jet velocity on jet flames. **Other topics:** Droplet and spray combustion.	14
4	**Metal Combustion: Importance of metal combustion in propulsion, physical description of metal combustion, Combustion mechanisms of Aluminum and Boron in various flow conditions.**	6
5	**Role of Combustion in Propulsion:** Basics of composite solid propellant deflagration, Principal ideas of combustion in liquid propellant rockets, Combustion in boundary layers and hybrid rockets, Combustion process in combustor of gas turbine engines and types of flame holders.	12
Total		39

Course Outcomes:
After successful completion, students will be able to

- Students can explain the fundamental thermodynamic and chemical principles governing combustion processes in propulsion systems.
- Students can analyze and solve problems involving energy release, flame temperature, and equilibrium composition in reacting flows.
- Evaluate the role of different types of combustion (e.g., premixed, diffusion, detonation) in air-breathing and non-air-breathing propulsion systems.
- Assess combustion stability issues and suggest design or operational modifications to enhance stability and reduce emissions.
- Students can explain combustion mechanisms of any fuels and oxidizers theoretically and numerically.

Recommended books:

1. An introduction to combustion by Stephen R. Turns, McGraw Hill Publications
2. Fuels and Combustion by Samir Sarkar, University Press
3. Combustion by Irwin Glassman, Aacademic Press.
4. Fundamental of Combustion by D.P. Mishra, PHI learning private limited.

Aircraft Dynamics - A Modeling Approach (AE 4225)
(Only for AE)

Contact Period: 3L per week **Full Marks: 100 [Credit – 03]**

Sl No.	Article	No. of Classes
1	Review of Basic Concepts of Aerodynamic Modeling	07
2	Modeling of Longitudinal Aerodynamic Forces and Moments	08
3	Modeling of Lateral Directional Aerodynamic Forces and Moments	08
4	Review of Basic Aircraft Performance and Modelinng of Thrust Forces and Moments	08
5	Aircraft Stability and Design for Trim condition	08
	Total	**39**

Book recommended: :
Aircraft Dynamics from Modeling to Simulation M. R. Napolitano

Computational Low Speed Aerodynamics (AE 4226)
(Only for AE)

Contact Period: 3L per week **Full Marks : 100 [Credit – 03]**

Sl No.	Article	No. of Classes
1	Introduction: Basic Solution: Point source; Point Doublet; Polynomials Two-Dimensional Version of Basic solutions Surface Distribution of Basic solutions	9
2	Singularity Elements and Influence Coefficients Two-Dimensional Point Singularity Elements; Two-Dimensional Constant Strength Singularity Elements; Two-Dimensional Linear Strength Singularity Elements Constant Strength Vortex Line Segment; Vortex Ring; Horseshoe Vortex	10
3	Two-Dimensional Numerical Solutions Point Singularity Solutions; Constant-Strength Singularity Solutions; Linearly Varying Singularity Strength Methods;	10
4	Three-Dimensional Numerical Solutions Lifting-Line Solution by Horseshoe Elements; Lifting-Surface Solution by Vortex Ring Elements	10
	Total	**39**

Book recommended:
1. Low Speed Aerodynamics, J. Katz and A. Plotkin

Mechatronics and Avionics (AE 4227)

Contact Periods – 3L **Full Marks: 100 [Credit–03]**
Prerequisite: None

Sl No.	Article	No. of Classes
1	**Overview of Mechatronics**: What is Mechatronics? Instrumentation and Control System. Concept of mechanism (link, joints, DOFs, 4 bar, crank-connecting rod)) and basic mechanical elements for motion transmission (gear, belt)	05
2	**Sensor and Actuators**: Introduction - Physical Principles, static and dynamics performance characteristics, Different type of Sensors, Actuators: Electrical, Hydraulic and Pneumatic Actuation Systems, Concept of Smart Material	05
3	**Mathematical Modeling of Physical Systems**: Physical & Mathematical Modeling of Mechanical, Electrical, and Electromechanical, Thermal, Fluid (Hydraulic & Pneumatic) and Multidisciplinary Physical Systems, Dynamic System Analytical.	05
4	**Electronics and hardware components for Mechatronics**: Computer interfacing, hardware for digital/analog interfacing	03
5	**Introduction to Control System**: Role of Controls in Mechatronics, Analog vs Digital, open loop vs feedback control, continuous vs discrete time control. Signals and Systems. Transfer Functions and Laplace transforms. Motion control – PID controllers	04
6	**Introduction to embedded systems:** System design, Microprocessors, Microcontrollers, DSP	03
7	**Human Computer Interaction**, Virtual Instruments, Man Machine interface, Virtual Reality	02
8	**Avionics - Sensing components** of an airplane and their functions - motions of a plane - Inertial Navigation – Sensors - Gyroscope- Principles , Gyro equations, Rate Gyros – Rate integration and free Gyro, Vertical and Directional Gyros, Laser Gyroscopes, Accelerometers. Direct reading compass, Measurement and control of Pressure, temperature, fuel quantity, spped, torque, engine vibration and power, Satellite navigation – GPS - system description -basic principles -position and velocity determination. IR sensor, Accelerometer sensor, Magnetic sensor, Load Cell, LVDT.	12
	Total	39

Books recommended:

1. Mechatronics by Robert H. Bishop
2. Mechatronics - D Silva
3. Collinson R.P.G. ‘Introduction to Avionics’, Chapman and Hall, 2002
4. Pallet, E.H.J. 'Aircraft Instruments & Integrated systems', McGraw-Hill, 2002
5. Myron Kyton, Walfred Fried, ‘Avionics Navigation Systems’, John Wiley& Sons,2000
6. Pallett, E.H.J. ‘Aircraft instruments, principles and applications’, Pitman publishing Ltd., London, 1995

Open Elective II (For 8th Semester)

Finite Element Method (AE 4261)

Contact Period: 3L per week **Full Marks : 100 [Credit – 03]**

Prerequisite: Fundamentals of Mechanics, Calculus, Matrix Algebra, Elementary numerical methods, Adequate familiarity with computer

Course objectives
Learning versatile and widely used numerical methods to approximately solve practical problems.

Sl No.	Article	No. of Classes
1	Overview of Finite Element Method (FEM): Basic concept; Historical background; Engineering applications; Introduction to Displacement, Force and Mixed Formulations.	03
2	Basic procedure : Discretization – Basic element shapes, Node numbering scheme; Interpolation model - Order of polynomial, Generalized and Natural co-ordinates, Convergence requirement, Patch test; Illustrations.	08
3	Derivation of Characteristic Matrices : Introduction to Direct approach, Variational approach (Raleigh-Ritz) and Weighted Residual Approach (Collocation, Least Square, Galerkin); Derivation of Finite Element equations using Variational and Weighted Residual Approach; Introduction to Strong and Weak Form formulation; Illustrations.	10
4	Assembly and Derivation of System Equations : Co-ordinate Transformation; Assemblage; Substitution of Boundary Conditions.	06
5	Numerical Solution of FEM Equations : Introduction to Band solver and Skyline technique; Applications to Equilibrium and Eigen value problems	09
6	Concluding Remarks: Comparison with other established numerical methods; Introduction to popular FEM packages.	03
	Total	**39**

Course Outcomes:
After successful completion, students will be able to

- Students will understand the fundamental concepts and formulations of the Finite Element Method.
- Students will be able to discretize engineering problems and derive element and global system equations.
- Students will apply FEM to solve structural, thermal, and other field problems using appropriate numerical techniques.
- Students will gain introductory experience with FEM software tools and assess the method's applicability to various engineering scenarios.

Books recommended:

- "The Finite Element Method" by S. S. Rao
- "An Introduction to The Finite Element Method" by J. N. Reddy
- "Fundamentals of Finite Element Analysis" by D. V. Hutton

Nonlinear Dynamics (AE 4262)

Contact Period: 3L per week **Full Marks : 100 [Credit – 03]**
Prerequisite : Knowledge of Dynamical Systems

Sl.	Article	No. of classes
1.	Introduction.	02
2.	One-Dimensional Flows, Fixed Points, Stability, Bifurcations – Ideal and Imperfect.	06
3.	Tow-Dimensional Flows, Phase Plane, Fixed points, Stability, Limit Cycles, Bifurcations Revisited, Index Theory.	11
4.	Analytical Methods, Averaging techniques, Perturbative Methods, Duffing and van der Pol Oscillators.	10
5.	One- Dimensional Maps, Bernoulli Shift, Logistic Map, Lyapunov Exponent.	05
6.	Strange Attractors, Chaos and Fractals.	05
Total		**39**

Books recommended:

1. Nonlinear Dynamics and Chaos - S. H. Strogatz
2. Chaos and Nonlinear Dynamics - R. C. Hilborn
3. An Exploration of Chaos - J. Argyris

Basics of Parallel Computation (AE 4263)

Contact Period: 3L per week **Full Marks : 100 [Credit – 03]**

Prerequisite: Basic programming knowledge in any one of FORTRAN, C, and C++

Sl No.	Module name and Topics	No. of Classes
1.	**Introduction to parallel computation:** Needs for parallel computations. Challenges of parallel programming- Parallel Programming Paradigms – Parallel Architecture - Overview of some parallel systems. Multiprocessors and multi-computers.	5
2.	**Modeling and analysis of parallel computations:** Efficiency characteristics of parallel computation: speedup, efficiency, scalability - Model analysis: determining the parallel method execution time, estimating the maximum possible parallelization, computational load balancing - The Amdahl's and Gustavson-Barsis's laws - Aggregating the computation model.	7
3.	**Parallel programming with MPI and communication :** Overview of the MPI standard. Point-to-point communication operations. Synchronous and asynchronous modes of data transmission. Collective operations. Derived data types. Process management. Logical topologies.	7
4.	**Basics of GPU Programming:** Introduction to GPU Architecture - History, graphics processors, graphics processing units, GPGPUs. Clock speeds, CPU / GPU comparisons, heterogeneity. Accelerators, parallel programming, CUDA / OpenCL / OpenACC,	10
5.	**Case study on parallel programming :** Algorithm development – selection of communication operations - Case studies: matrix computations, solving partial differential equations – 1D Wave Equation.	10
	Total	**39**

Course Outcomes:
After successful completion, students will be able to

- Understand the need for parallel computing and the challenges involved in parallel program design.
- Analyze and model the performance of parallel algorithms using metrics such as speedup, efficiency, and scalability.
- Develop parallel programs using MPI for communication in distributed memory systems.
- Gain foundational knowledge of GPU architectures and implement basic GPU programs using CUDA and OpenCL.
- Design and implement parallel solutions for computational problems such as matrix operations and differential equations.

Books:

1. Grama, Ananth, et al. Introduction to parallel computing. Pearson Education, 2003.
2. Pacheco, Peter. An introduction to parallel programming. Elsevier, 2011.
3. Kirk, David B., and W. Hwu Wen-Mei. Programming massively parallel processors: a hands-on approach. Morgan kaufmann, 2016.
4. Schmidt, Bertil, et al. Parallel programming: concepts and practice. Morgan Kaufmann, 2017.
5. Cai, Yiyu, and Simon See, eds. GPU computing and applications. Singapore: Springer, 2015.