ANNA UNIVERSITY, CHENNAI
AFFILIATED COLLEGES
REGULATIONS - 2017
M.E. AERONAUTICAL ENGINEERING
CHOICE BASED CREDIT SYSTEM

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs):

I. **PEO 1:** Successful Moulding of Graduate into Aeronautical Engineering Professional: Graduates of the programme will acquire adequate knowledge both in practical and theoretical domains in the field of Aeronautical Engineering through rigorous post graduate education.

II. **PEO 2:** Successful Career Development:
Graduates of the programme will have successful technical and managerial career in Aeronautical Engineering industries and the allied management.

III. **PEO 3:** Contribution to Aeronautical Engineering Field:
Graduates of the programme will have innovative ideas and potential to contribute for the development and current needs of the Aviation industries.

IV. **PEO 4:** Sustainable interest for Lifelong learning:
Graduates of the programme will have sustained interest to learn and adapt new Technology developments to meet the changing industrial scenarios.

PROGRAMME OUTCOMES (POs)

On successful completion of the programme,

1. Post Graduate will acquire the ability to design and conduct experiments, as well as to analyze and interpret data in the field of Aeronautical Engineering.
2. Post Graduate will have the ability to design a system or a component to meet the design requirements with constraints exclusively meant for Aeronautical Engineering.
3. Post Graduate will become familiar with modern engineering tools and analyze problems within the domains of Aeronautical Engineering
4. Post Graduate will acquire an understanding of professional and ethical responsibility with reference to their career in the field of Aeronautical Engineering and other allied professional fields.
5. Post Graduate will be able to communicate effectively both in verbal and nonverbal forms.
6. Post Graduate will be trained towards developing and understanding the importance of design and development of Airplanes from system integration point of view.
7. Post Graduate will be capable of understanding the value of lifelong learning.
8. Post Graduate will exhibit the awareness of contemporary issues focusing on the necessity to develop new materials, design and testing methods for the solution of problems related to aircraft industry.
9. Post Graduate will have a firm scientific, technological and communication base that helps him to find a placement in the aircraft industry and Research & Development organizations related to Aeronautical Engineering and other professional fields.
10. Post Graduate will be capable of doing doctoral studies and research in inter and multidisciplinary areas.

Mapping of PEOs with Pos

Programme Educational Objectives	Programme Outcomes									
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
I	✓	✓	✓	✓				✓		✓
II				✓	✓	✓		✓	✓	
III		✓		✓		✓		✓	✓	
IV			✓				✓	✓		✓

MAPPING OF POS WITH SUBJECTS

YEAR	SEM	COURSE TITLE	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
YEAR I	SEM I	Advanced Mathematical Methods	✓		✓				✓		✓	✓
		Aerodynamics	✓	✓	✓	✓		✓	✓		✓	✓
		Aircraft Structural Mechanics	✓	✓	✓	✓		✓	✓		✓	✓
		Aerospace Propulsion	✓	✓	✓	✓		✓	✓		✓	✓
		Theory of Vibrations	✓	✓	✓			✓			✓	✓
		Professional Elective I										
		Practical										
		Aerodynamics Laboratory	✓	✓	✓	✓	✓	✓	✓	✓		
		Technical Seminar - I			✓	✓	✓		✓			
	SEM II	Flight Mechanics	✓	✓				✓	✓	✓		✓
		Finite Element Methods	✓	✓	✓	✓		✓	✓			✓
		Computational Fluid Dynamics for Aerospace Applications	✓	✓	✓	✓		✓	✓			✓
		Composite Materials and Structures	✓	✓				✓	✓	✓		✓
		Professional Elective II										
		Professional Elective III										
		Practical										
		Structures Laboratory	✓	✓	✓	✓	✓	✓	✓	✓		
		CFD/FEA Laboratory	✓	✓	✓	✓	✓	✓	✓	✓		
YEAR II	SEM III	Professional Elective IV										
		Professional Elective V										
		Practical										
		Project Work Phase I	✓	✓	✓	✓	✓	✓	✓	✓	✓	
		Technical Seminar II			✓	✓	✓		✓			
	SEM IV	Project Work Phase II	✓	✓	✓	✓	✓	✓	✓	✓	✓	

List of Electives
MAPPING OF POS WITH SUBJECTS
Semester: I Electives

S.No.	Course Title	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
1	Boundary Layer Theory	✓		✓			✓		✓		
2	Aircraft Design	✓	✓	✓	✓		✓	✓	✓	✓	✓
3	Theory of Elasticity	✓	✓				✓		✓		
4	Rocketry and Space Mechanics	✓	✓		✓		✓			✓	✓
5	Experimental Stress Analysis	✓	✓	✓			✓	✓	✓	✓	✓

Semester: II Electives

S.No	Course Title	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
1	Theory of Plates and Shell	✓	✓				✓		✓		✓
2	High Temperature Problems in Structures		✓	✓			✓		✓	✓	
3	Fatigue and Fracture Mechanics	✓	✓	✓			✓		✓		✓
4	Industrial Aerodynamics	✓	✓		✓		✓	✓	✓	✓	
5	Hypersonic Aerodynamics		✓	✓			✓		✓		✓
6	Computational Heat Transfer		✓	✓			✓		✓		✓
7	Wind power Engineering	✓	✓	✓	✓		✓		✓		
8	Advanced Propulsion System	✓	✓	✓			✓				✓
9	Data Analytics	✓	✓	✓			✓			✓	✓

Semester: III Electives

S.No	Course Title	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
1	Aero Elasticity		✓				✓				
2	Design and Analysis of Turbo Machines	✓	✓	✓			✓				
3	Helicopter Aerodynamics		✓				✓				
4	Experimental Aerodynamics	✓	✓				✓	✓	✓	✓	
5	High Temperature Gas Dynamics		✓	✓							✓
6	High Speed Jet Flows		✓	✓							
7	Combustion in Jet and Rocket Engines		✓							✓	
8	Propeller Aerodynamics		✓	✓							✓
9	Aircraft Guidance and Control	✓	✓	✓			✓				✓
10	Avionics	✓	✓	✓			✓			✓	

ANNA UNIVERSITY, CHENNAI

AFFILIATED INSTITUTIONS

REGULATIONS 2017

M.E. AERONAUTICAL ENGINEERING

CHOICE BASED CREDIT SYSTEMS
I TO IV SEMESTERS (FULL TIME) CURRICULUM AND SYLLABUS

SEMESTER I

SL. NO.	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIOD	L	T	P	C
THEORY								
1.	MA5151	Advanced Mathematical Methods	FC	4	4	0	0	4
2.	AO5151	Aerodynamics	PC	3	3	0	0	3
3.	AO5101	Aircraft Structural Mechanics	PC	5	3	2	0	4
4.	AO5102	Aerospace Propulsion	FC	5	3	2	0	4
5.	AO5103	Theory of Vibrations	PC	3	3	0	0	3
6.		Professional Elective I	PE	3	3	0	0	3
PRACTICAL								
7.	AO5161	Aerodynamics Laboratory	PC	4	0	0	4	2
8.	AO5111	Technical Seminar – I	EEC	2	0	0	2	1
			TOTAL	**29**	**19**	**4**	**6**	**24**

SEMESTER II

SL. NO.	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIOD	L	T	P	C
THEORY								
1.	AO5251	Flight Mechanics	PC	3	3	0	0	3
2.	AO5252	Finite Element Methods	PC	5	3	2	0	4
3.	AO5253	Computational Fluid Dynamics for Aerospace Applications	PC	3	3	0	0	3
4.	AO5254	Composite Materials and Structures	PC	3	3	0	0	3
5.		Professional Elective II	PE	3	3	0	0	3
6.		Professional Elective III	PE	3	3	0	0	3
PRACTICAL								
7	AO5261	Structures Laboratory	PC	4	0	0	4	2
8	AO5211	CFD/FEA Laboratory	EEC	4	0	0	4	2
			TOTAL	**28**	**18**	**2**	**8**	**23**

SEMESTER III

SL. NO	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIOD	L	T	P	C
THEORY								
1.		Professional Elective IV	PE	3	3	0	0	3
2.		Professional Elective V	PE	3	3	0	0	3
PRACTICAL								
3.	AO5312	Project Work Phase I	EEC	12	0	0	12	6
4.	AO5311	Technical Seminar - II	EEC	2	0	0	2	1
			TOTAL	**20**	**6**	**0**	**14**	**13**

SEMESTER IV

SL. NO	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIOD	L	T	P	C
PRACTICAL								
1.	AO5411	Project Work Phase II	EEC	24	0	0	24	12
			TOTAL	**24**	**0**	**0**	**24**	**12**

TOTAL CREDITS TO BE EARNED FOR THE AWARD OF THE DEGREE = 72

FOUNDATION COURSES (FC)

SL. NO.	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
1.	MA5151	Advanced Mathematical Methods	FC	4	4	0	0	4
2.	AO5102	Aerospace Propulsion	FC	5	3	2	0	4

PROFESSIONAL CORE (PC)

SL. NO.	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
1.	AO5151	Aerodynamics	PC	5	3	2	0	4
2.	AO5101	Aircraft Structural Mechanics	PC	5	3	0	0	3
3.	AO5103	Theory of Vibrations	PC	3	3	0	0	3
4.	AO5161	Aerodynamics Laboratory	PC	4	0	0	4	2
5.	AO5251	Flight Mechanics	PC	5	3	0	0	3
6.	AO5252	Finite Element Methods	PC	5	3	2	0	4
7.	AO5253	Computational Fluid Dynamics for Aerospace Applications	PC	3	3	0	0	3
8.	AO5254	Composite Materials and Structures	PC	3	3	0	0	3
9.	AO5261	Structures Laboratory	PC	4	0	0	4	2

LIST OF ELECTIVES FOR M.E. AERONAUTICAL ENGINEERING

SEMESTER I (Elective I)

SL. NO.	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIOD	L	T	P	C
1	AO5001	Boundary Layer Theory	PE	3	3	0	0	3
2	AO5002	Aircraft Design	PE	3	3	0	0	3
3	AO5003	Theory of Elasticity	PE	3	3	0	0	3
4	AO5071	Rocketry and Space Mechanics	PE	3	3	0	0	3
5	AO5004	Experimental Stress Analysis	PE	3	3	0	0	3

SEMESTER II (Elective II & III)

SL. NO	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIOD	L	T	P	C
1	AO5005	Theory of Plates and Shells	PE	3	3	0	0	3
2	AO5006	High Temperature Problems in Structures	PE	3	3	0	0	3
3	AO5074	Fatigue and Fracture Mechanics	PE	3	3	0	0	3
4	AO5007	Industrial Aerodynamics	PE	3	3	0	0	3
5	AO5091	Hypersonic Aerodynamics	PE	3	3	0	0	3
6	AO5072	Computational Heat Transfer	PE	3	3	0	0	3
7	AO5008	Wind Power Engineering	PE	3	3	0	0	3
8	AO5073	Advanced Propulsion Systems	PE	3	3	0	0	3
9	IL5091	Data Analytics	PE	3	3	0	0	3

SEMESTER III (Elective IV & V)

SL. NO	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIOD	L	T	P	C
1	AO5010	Aero Elasticity	PE	3	3	0	0	3
2	EY5092	Design and Analysis of Turbomachines	PE	3	3	0	0	3
3	AO5011	Helicopter Aerodynamics	PE	3	3	0	0	3
4	AO5012	Experimental Aerodynamics	PE	3	3	0	0	3
5	AO5013	High Temperature Gas Dynamics	PE	3	3	0	0	3
6	AO5075	High Speed Jet Flows	PE	3	3	0	0	3
7	AO5014	Combustion in Jet and Rocket Engines	PE	3	3	0	0	3
8	AO5015	Propeller Aerodynamics	PE	3	3	0	0	3
9	AO5009	Aircraft Guidance and Control	PE	3	3	0	0	3
10	AO5092	Avionics	PE	3	3	0	0	3

EMPLOYABILITY ENHANCEMENT COURSES (EEC)

SL. NO.	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
1.	AO5211	CFD/FEA Laboratory	EEC	4	0	0	4	2
2.	AO5312	Project Work Phase I	EEC	12	0	0	12	6
3.	AO5311	Technical Seminar - II	EEC	2	0	0	2	1
4.	AO5411	Project Work Phase II	EEC	24	0	0	24	12

MA5151 **ADVANCED MATHEMATICAL METHODS** **L T P C**
4 0 0 4

OBJECTIVES :

The main objective of this course is to provide the student with a repertoire of mathematical methods that are essential to the solution of advanced problems encountered in the fields of applied physics and engineering. This course covers a broad spectrum of mathematical techniques such as Laplace Transform, Fourier Transform, Calculus of Variations, Conformal Mapping and Tensor Analysis. Application of these topics to the solution of problems in physics and engineering is stressed.

UNIT I LAPLACE TRANSFORM TECHNIQUES FOR PARTIAL DIFFERENTIAL EQUATIONS 12

Laplace transform : Definitions – Properties – Transform error function – Bessel's function - Dirac delta function – Unit step functions – Convolution theorem – Inverse Laplace transform : Complex inversion formula – Solutions to partial differential equations : Heat equation – Wave equation.

UNIT II FOURIER TRANSFORM TECHNIQUES FOR PARTIAL DIFFERENTIAL EQUATIONS 12

Fourier transform : Definitions – Properties – Transform of elementary functions – Dirac delta function – Convolution theorem – Parseval's identity – Solutions to partial differential equations : Heat equation – Wave equation – Laplace and Poisson's equations.

UNIT III CALCULUS OF VARIATIONS 12

Concept of variation and its properties – Euler's equation – Functional dependant on first and higher order derivatives – Functionals dependant on functions of several independent variables – Variational problems with moving boundaries – Isoperimetric problems – Direct methods – Ritz and Kantorovich methods.

UNIT IV CONFORMAL MAPPING AND APPLICATIONS 12

Introduction to conformal mappings and bilinear transformations – Schwarz Christoffel transformation – Transformation of boundaries in parametric form – Physical applications : Fluid flow and heat flow problems.

UNIT V TENSOR ANALYSIS 12

Summation convention – Contravariant and covariant vectors – Contraction of tensors – Inner product – Quotient law – Metric tensor – Christoffel symbols – Covariant differentiation – Gradient - Divergence and curl.

TOTAL : 60 PERIODS

OUTCOMES :

After completing this course, students should demonstrate competency in the following skills:

- Application of Laplace and Fourier transforms to initial value, initial–boundary value and boundary value problems in Partial Differential Equations.
- Maximizing and minimizing the functional that occur in various branches of Engineering Disciplines.
- Construct conformal mappings between various domains and use of conformal mapping in studying problems in physics and engineering particularly to fluid flow and heat flow problems.
- Understand tensor algebra and its applications in applied sciences and engineering and develops ability to solve mathematical problems involving tensors.
- Competently use tensor analysis as a tool in the field of applied sciences and related fields.

REFERENCES :
1. Andrews L.C. and Shivamoggi, B., "Integral Transforms for Engineers", Prentice Hall of India Pvt. Ltd., New Delhi, 2003.
2. Elsgolc, L.D., "Calculus of Variations", Dover Publications Inc., New York, 2007.
3. Mathews, J. H., and Howell, R.W., "Complex Analysis for Mathematics and Engineering", 5th Edition, Jones and Bartlett Publishers, 2006.
4. Kay, D. C., "Tensor Calculus", Schaum's Outline Series, Tata McGraw Hill Edition, 2014.
5. Naveen Kumar, "An Elementary Course on Variational Problems in Calculus ", Narosa Publishing House, 2005.
6. Saff, E.B and Snider, A.D, "Fundamentals of Complex Analysis with Applications in Engineering, Science and Mathematics", 3rd Edition, Pearson Education, New Delhi, 2014.
7. Sankara Rao, K., "Introduction to Partial Differential Equations", Prentice Hall of India Pvt. Ltd., New Delhi, 1997.
8. Spiegel, M.R., "Theory and Problems of Complex Variables and its Applications", Schaum's Outline Series, McGraw Hill Book Co., 1981.
9. Ramaniah. G. "Tensor Analysis", S. Viswanathan Pvt. Ltd., 1990.

AO5151 AERODYNAMICS L T P C
3 0 0 3

OBJECTIVES
- To introduce the students the fundamental concepts and topic related to aerodynamics of flight vehicles like fundamental forms of flow, aerodynamic coefficient, incompressible and compressible flow theories, viscous flow measurements and various configuration of aircraft and wings.

UNIT I INTRODUCTION TO AERODYNAMICS 9
Hot air balloon and aircrafts, Various types of airplanes, Wings and airfoils, lift and Drag, Centre of pressure and aerodynamic centre, Coefficient of pressure, moment coefficient, Continuity and Momentum equations, Point source and sink, doublet, Free and Forced Vortex, Uniform parallel flow, combination of basic flows, Pressure and Velocity distributions on bodies with and without circulation in ideal and real fluid flows, Magnus effect

UNIT II INCOMPRESSIBLE FLOW THEORY 9
Conformal Transformation, Kutta condition, Karman – Trefftz profiles, Thin aerofoil Theory and its applications. Vortex line, Horse shoe vortex, Biot - Savart law, lifting line theory

UNIT III COMPRESSIBLE FLOW THEORY 9
Compressibility, Isentropic flow through nozzles, shocks and expansion waves, Rayleigh and Fanno Flow, Potential equation for compressible flow, small perturbation theory, Prandtl- Glauert Rule, Linearised supersonic flow, Method of characteristics

UNIT IV AIRFOILS, WINGS AND AIRPLANE CONFIGURATION IN HIGH SPEED FLOWS 9
Critical Mach number, Drag divergence Mach number, Shock stall, super critical airfoils, Transonic area rule, Swept wings (ASW and FSW), supersonic airfoils, wave drag, delta wings, Design considerations for supersonic airplanes

UNIT V VISCOUS FLOW AND FLOW MEASUREMENTS 9
Basics of viscous flow theory – Boundary Layer – Displacement, momentum and Energy Thickness – Laminar and Turbulent boundary layers – Boundary layer over flat plate – Blasius Solution Introduction to wind tunnel, Types of wind tunnel, Scale model, Important testing parameters, Calibration of test section, Measurement of force, moment and pressure, scale effect, Flow visualization techniques

TOTAL : 45 PERIODS

OUTCOME:
Upon completion of the course, students will understand the behaviour of airflow over bodies with particular emphasis on airfoil sections in the incompressible flow regime.

REFERENCES

1. E.L. Houghton and N.B. Caruthers, Aerodynamics for Engineering Students, Edward Arnold Publishers Ltd., London (First Indian Edition), 1988
2. J.D. Anderson, "Fundamentals of Aerodynamics", McGraw-Hill Book Co., New York,1985.
3. Rathakrishnan.E., Gas Dynamics, Prentice Hall of India, 1995.
4. Shapiro, A.H., Dynamics & Thermodynamics of Compressible Fluid Flow, Ronald Press, 1982.
5. W.H. Rae and A. Pope, "Low speed Wind Tunnel Testing", John Wiley Publications, 1984.
6. Zucrow, M.J., and Anderson, J.D., Elements of gas dynamics McGraw-Hill Book Co., New York, 1989.

AO5101	**AIRCRAFT STRUCTURAL MECHANICS**	**L T P C**
		3 2 0 4

OBJECTIVE
- To make students learn important technical aspects on theory of bending, shear flow in open and closed sections, stability problems in structures with various modes of loading and also impart knowledge on how to analyze aircraft structural components under various forms of loading.

UNIT I BENDING OF BEAMS 12
Elementary theory of bending – Introduction to semi-monocoque structures - Stresses in beams of symmetrical and unsymmetrical sections -Box beams – General formula for bending stresses-principal axes method – Neutral axis method.

UNIT II SHEAR FLOW IN OPEN SECTIONS 9
Shear stresses in beams – Shear flow in stiffened panels - Shear flow in thin walled open tubes – Shear centre – Shear flow in open sections with stiffeners.

UNIT III SHEAR FLOW IN CLOSED SECTIONS 15
Shear flow in closed sections with stiffeners– Angle of twist - Shear flow in two flange and three flange box beams – Shear centre - Shear flow in thin walled closed tubes - Bredt-Batho theory - Torsional shear flow in multi cell tubes - Flexural shear flow in multi cell stiffened structures.

UNIT IV STABILITY PROBLEMS 12
Stability problems of thin walled structures– Buckling of sheets under compression, shear, bending and combined loads - Crippling stresses by Needham's and Gerard's methods–Sheet stiffener panels-Effective width, Inter rivet and sheet wrinkling failures-Tension field web beams(Wagner's).

UNIT V ANALYSIS OF AIRCRAFT STRUCTURAL COMPONENTS 12
Loads on Wings – Schrenk's curve - Shear force, bending moment and torque distribution along the span of the Wing. Loads on fuselage - Shear and bending moment distribution along the length of the fuselage. Analysis of rings and frames.

TOTAL: 60 PERIODS

OUTCOME:
Upon completion of the course, students will get knowledge on different types of beams and columns subjected to various types of loading and support conditions with particular emphasis on aircraft structural components.

REFERENCES
1. E.F. Bruhn, “Analysis and Design of Flight Vehicle Structures”, Tristate Offset Co., 1980.
2. Megson, T.M.G; Aircraft Structures for Engineering Students, Edward Arnold, 1995.
3. Peery, D.J. and Azar, J.J., Aircraft Structures, 2nd Edition, McGraw-Hill, New York, 1993.
4. Rivello, R.M., Theory and Analysis of Flight structures, McGraw-Hill, N.Y., 1993.
5. Stephen P. Tinnoshenko & S.woinowsky Krieger, Theory of Plates and Shells, 2nd Edition, McGraw-Hill, Singapore, 1990.

AO5102 AEROSPACE PROPULSION

	L	T	P	C
	3	2	0	4

OBJECTIVES:

- To impart knowledge to students about fundamental principles of aircraft hypersonic and rocket propulsion and also to make them familiarize with electric nuclear and solar space propulsion methods.

UNIT I ELEMENTS OF AIRCRAFT PROPULSION 12

Classification of power plants - Methods of aircraft propulsion – Propulsive efficiency – Specific fuel consumption - Thrust and power- Factors affecting thrust and power- Illustration of working of Gas turbine engine - Characteristics of turboprop, turbofan and turbojet , Ram jet, Scram jet – Methods of Thrust augmentation.

UNIT II PROPELLER THEORY 12

Momentum theory, Blade element theory, combined blade element and momentum theory, propeller power losses, propeller performance parameters, prediction of static thrust- and in flight, negative thrust, prop fans, ducted propellers, propeller noise, propeller selection, propeller charts.

UNIT III INLETS, NOZZLES AND COMBUSTION CHAMBERS 12

Subsonic and supersonic inlets – Relation between minimum area ratio and external deceleration ratio – Starting problem in supersonic inlets –Modes of inlet operation, jet nozzle – Efficiencies – Over expanded, under and optimum expansion in nozzles – Thrust reversal. Classification of Combustion chambers - Combustion chamber performance – Flame tube cooling – Flame stabilization.

UNIT IV AXIAL FLOW COMPRESSORS, FANS AND TURBINES 12

Introduction to centrifugal compressors- Axial flow compressor- geometry- twin spools- three spools- stage analysis- velocity polygons- degree of reaction – radial equilibrium theory-performance maps- axial flow turbines- geometry- velocity polygons- stage analysis- performance maps- thermal limit of blades and vanes.

UNIT V ROCKET AND ELECTRIC PROPULSION 12

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

TOTAL : 60 PERIODS

OUTCOME:

Upon completion of the course, students will learn the principles of operation and design of aircraft and spacecraft power plants.

REFERENCES
1. Cohen, H. Rogers, G.F.C. and Saravanamuttoo,H.I.H, Gas Turbine Theory, Longman,1989
2. G.C. Oates, “Aerothermodynamics of Aircraft Engine Components”, AIAA Education Series, 1985.
3. G.P.Sutton, “Rocket Propulsion Elements”, John Wiley & Sons Inc., New York, 5th Edition, 1986.
4. Hill, P.G. and Peterson, C.R. Mechanics and Thermodynamics of Propulsion, Addison – Wesley Longman Inc. 1999
5. W.P.Gill, H.J.Smith & J.E. Ziurys, “Fundamentals of Internal Combustion Engines as applied to Reciprocating, Gas turbine & Jet Propulsion Power Plants”, Oxford & IBH Publishing Co., 1980.

AO5103	**THEORY OF VIBRATIONS**	**L T P C**
		3 0 0 3

OBJECTIVE:

- To study the effect of time dependent forces on mechanical systems and to get the natural characteristics of system with more degree of freedom systems.
- To study the aeroelastic effects of aircraft wing.

UNIT I SINGLE DEGREE OF FREEDOM SYSTEMS 10

Simple harmonic motion, definition of terminologies, Newton’s Laws, D’Alembert’s principle, Energy methods. Free and forced vibrations with and without damping, base excitation, and vibration measuring instruments.

UNIT II MULTI-DEGREES OF FREEDOM SYSTEMS 12

Two degrees of freedom systems, Static and dynamic couplings, eigen values, eigen vectors and orthogonality conditions of eigen vectors, Vibration absorber, Principal coordinates, Principal modes. Hamilton’s Principle, Lagrange’s equation and its applications.

UNIT III VIBRATION OF ELASTIC BODIES 10

Transverse vibrations of strings, Longitudinal, Lateral and Torsional vibrations. Approximate methods for calculating natural frequencies.

UNIT IV EIGEN VALUE PROBLEMS & DYNAMIC RESPONSE OF LARGE SYSTEMS 8

Eigen value extraction methods – Subspace hydration method, Lanczos method – Eigen value reduction method – Dynamic response of large systems – Implicit and explicit methods.

UNIT V ELEMENTS OF AEROELASTICITY 5

Aeroelastic problems – Collar’s triangle of forces – Wing divergence – Aileron control reversal – Flutter.

TOTAL : 45 PERIODS

OUTCOME:

Upon completion of the course, students will learn the dynamic behaviour of different aircraft components and the interaction among the aerodynamic, elastic and inertia forces

REFERENCES
1. F.S. Tse., I.F. Morse and R.T. Hinkle, “Mechanical Vibrations”, Prentice-Hall of India, 1985.
2. Fung, Y.C., “An Introduction to the Theory of Aeroelasticity”, John Wiley & Sons Inc., New York, 1985.
3. Kenneth G. McConnell, Paulo S. Varoto Vibration Testing: Theory and Practice 2nd Edition, 2008
4. Meirovitch, L. “Elements of Vibration Analysis”, McGraw-Hill Inc., 1986.

5. Rao.J.S. and Gupta.K. “Theory and Practice of Mechanical Vibrations”, Wiley Eastern Ltd., New Delhi, 1999.
6. Thomson W.T, Marie Dillon Dahleh, “Theory of Vibrations with Applications”, Prentice Hall, 1997
7. Timoshenko, S. “Vibration Problems in Engineering”, John Wiley & Sons, Inc., 1987.

AO5161 AERODYNAMICS LABORATORY L T P C
0 0 4 2

LIST OF EXPERIMENTS

1. Calibration of subsonic wind tunnel
2. Pressure distribution over a smooth and rough cylinders
3. Pressure distribution over a symmetric aerofoil section
4. Pressure distribution over a cambered aerofoil section
5. Force and moment measurements using wind tunnel balance
6. Pressure distribution over a wing of symmetric aerofoil section
7. Pressure distribution over a wing of cambered aerofoil section
8. Flow visualization studies in incompressible flows
9. Calibration of supersonic wind tunnel
10. Supersonic flow visualization studies

TOTAL: 60 PERIODS

LABORATORY EQUIPMENTS REQUIREMENTS

1. Subsonic wind tunnel
2. Rough and smooth cylinder
3. Symmetrical Cambered aerofoil
4. Wind tunnel balance
5. Schlieren system
6. Pressure Transducers
7. Supersonic wind tunnel

OUTCOME:

Upon completion of the course, students will be in a position to use wind tunnel for pressure and force measurements on various models

AO5251 FLIGHT MECHANICS L T P C
3 0 0 3

OBJECTIVE

- To impart knowledge to students on aircraft performance in level, climbing, gliding and accelerated flight modes and also various aspects of stability and control in longitudinal, lateral and directional modes.

UNIT I PRINCIPLES OF FLIGHT 9

Physical properties and structure of the atmosphere, International Standard Atmosphere, Temperature, pressure and altitude relationship, Measurement of speed – True, Indicated and Equivalent air speed, Streamlined and bluff bodies, Various Types of drag in airplanes, Drag polar, Methods of drag reduction of airplanes.

UNIT II AIRCRAFT PERFORMANCE IN LEVEL, CLIMBING AND GLIDING FLIGHTS 8

Straight and level flight, Thrust required and available, Power required and available, Effect of altitude on thrust and power, Conditions for minimum drag and minimum power required, Gliding and Climbing flight, Range and Endurance

UNIT III ACCELERATED FLIGHT 9

Take off and landing performance, Turning performance, horizontal and vertical turn, Pull up and pull down, maximum turn rate, V-n diagram with FAR regulations.

UNIT IV LONGITUDINAL STABILITY AND CONTROL 10

Degrees of freedom of a system, static and dynamic stability, static longitudinal stability, Contribution of individual components, neutral point, static margin, Hinge moment, Elevator control effectiveness, Power effects, elevator angle to trim, elevator angle per g, maneuver point, stick force gradient, aerodynamic balancing, Aircraft equations of motion, stability derivatives, stability quartic, Phugoid motion

UNIT V LATERAL, DIRECTIONAL STABILITY AND CONTROL 9

Yaw and side slip, Dihedral effect, contribution of various components, lateral control, aileron control power, strip theory, aileron reversal, weather cock stability, directional control, rudder requirements, dorsal fin, One engine inoperative condition, Dutch roll, spiral and directional divergence, autorotation and spin

TOTAL: 45 PERIODS

OUTCOME:

Upon completion of the course, students will understand the static, dynamic longitudinal, directional and lateral stability and control of airplane, effect of maneuvers.

REFERENCES

1. Babister, A.W. Aircraft stability and response, Pergamon Press, 1980.
2. Clancey,L.J. Aerodynamics, Pitman, 1986.
3. Houghton, E.L., and Caruthers, N.B., Aerodynamics for engineering students, Edward Arnold Publishers, 1988.
4. Kuethe, A.M., and Chow, C.Y., Foundations of Aerodynamics, John Wiley & Sons, 1982.
5. McCormic, B.W., Aerodynamics, Aeronautics & Flight Mechanics John Wiley, 1995.
6. Nelson, R.C. Flight Stability & Automatic Control, McGraw-Hill, 1989.
7. Perkins C.D., & Hage, R.E. Airplane performance, stability and control, Wiley Toppan, 1974.

AO5252	FINITE ELEMENT METHODS	L T P C
		3 2 0 4

OBJECTIVES:

- To make students learn using Finite element techniques to solve problems related to discrete, continuum and isoparametric elements. And also to introduce solution schemes for static, dynamic and stability problems.

UNIT I INTRODUCTION 12

Review of various approximate methods – Rayleigh-Ritz, Galerkin and Finite Difference Methods - Stiffness and flexibility matrices for simple cases - Basic concepts of finite element method - Formulation of governing equations and convergence criteria.

UNIT II DISCRETE ELEMENTS 14

Structural analysis of bar and beam elements for static and dynamic loadings. Bar of varying section – Temperature effects

Program Development and use of software package for application of bar and beam elements for static, dynamic and stability analysis.

UNIT III CONTINUUM ELEMENTS 14

Plane stress, Plane strain and Axisymmetric problems – CST Element – LST Element. Consistent and lumped load vectors. Use of local co-ordinates. Numerical integration. Application to heat transfer problems.

Solution for 2-D problems (static analysis and heat transfer) using software packages.

UNIT IV ISOPARAMETRIC ELEMENTS 12

Definition and use of different forms of 2-D and 3-D elements. - Formulation of element stiffness matrix and load vector.

Solution for 2-D problems (static analysis and heat transfer) using software packages.

UNIT V SOLUTION SCHEMES 8

Different methods of solution of simultaneous equations governing static, dynamics and stability problems. General purpose Software packages.

TOTAL: 60 PERIODS

OUTCOME:

Upon completion of the course, students will learn the concept of numerical analysis of structural components

REFERENCES

1. C.S. Krishnamurthy, "Finite Elements Analysis", Tata McGraw-Hill, 1987.
2. K.J. Bathe and E.L. Wilson, "Numerical Methods in Finite Elements Analysis", Prentice Hall of India Ltd., 1983.
3. Robert D. Cook, David S. Malkus, Michael E. Plesha and Robert J. Witt "Concepts and Applications of Finite Element Analysis", 4th Edition, John Wiley & Sons, 2002.
4. S.S.Rao, "Finite Element Method in Engineering", Butterworth, Heinemann Publishing, 3rd Edition, 1998
5. Segerlind,L.J. "Applied Finite Element Analysis", Second Edition, John Wiley and Sons Inc., New York, 1984.
6. Tirupathi R. Chandrupatla and Ashok D. Belegundu, Introduction to Finite Elements in Engineering, Prentice Hall, 2002

AO5253	COMPUTATIONAL FLUID DYNAMICS FOR AEROSPACE APPLICATIONS	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To introduce to the students various numerical solution methods pertaining to grid generation, time dependant and panel methods and also techniques pertaining to transonic small perturbation force.

UNIT I NUMERICAL SOLUTIONS OF SOME FLUID DYNAMICAL PROBLEMS 9

Basic fluid dynamics equations, Equations in general orthogonal coordinate system, Body fitted coordinate systems, Stability analysis of linear system. Finding solution of a simple gas dynamic problem, Local similar solutions of boundary layer equations, Numerical integration and shooting technique.

Numerical solution for CD nozzle isentropic flows and local similar solutions of boundary layer equations.

UNIT II GRID GENERATION 9

Need for grid generation – Various grid generation techniques – Algebraic, conformal and numerical grid generation – importance of grid control functions – boundary point control – orthogonality of grid lines at boundaries.

Elliptic grid generation using Laplace's equations for geometries like airfoil and CD nozzle.

UNIT III TRANSONIC RELAXATION TECHNIQUES 9

Small perturbation flows, Transonic small perturbation (TSP) equations, Central and backward difference schemes, conservation equations and shockpoint operator, Line relaxation techniques, Acceleration of convergence rate, Jameson's rotated difference scheme -stretching of coordinates, shock fitting techniques Flow in body fitted coordinate system.

Numerical solution of 1-D conduction- convection energy equation using time dependentmethods using both implicit and explicit schemes – application of time split method for the above equation and comparison of the results.

UNIT IV TIME DEPENDENT METHODS 9

Stability of solution, Explicit methods, Time split methods, Approximate factorization scheme, Unsteady transonic flow around airfoils. Some time dependent solutions of gas dynamic problems. Numerical solution of unsteady 2-D heat conduction problems using SLOR methods

UNIT V PANEL METHODS 9

Elements of two and three dimensional panels, panel singularities. Application of panel methods to incompressible, compressible, subsonic and supersonic flows.
Numerical solution of flow over a cylinder using 2-D panel methods using both vertex and source panel methods for lifting and non lifting cases respectively.

TOTAL: 45 PERIODS

OUTCOME:

Upon completion of the course, students will learn the flow of dynamic fluids by computational methods.

REFERENCES

1. A.A. Hirsch, ‘Introduction to Computational Fluid Dynamics”, McGraw-Hill, 1989.
2. C.Y.Chow, “Introduction to Computational Fluid Dynamics”, John Wiley, 1979.
3. H.J. Wirz and J.J. Smeldern “Numerical Methods in Fluid Dynamics”, McGraw-Hill & Co., 1978.
4. John D. Anderson, JR” Computational Fluid Dynamics”, McGraw-Hill Book Co., Inc., New York, 1995.
5. T.J. Chung, Computational Fluid Dynamics, Cambridge University Press, 2002
6. T.K.Bose, “Computation Fluid Dynamics” Wiley Eastern Ltd., 1988.

AO5254 COMPOSITE MATERIALS AND STRUCTURES L T P C
3 0 0 3

OBJECTIVE:

- To impart knowledge to the students on the macro mechanics of composite materials, analysis and manufacturing methods of composite materials and introduce failure theories of composites.

UNIT I INTRODUCTION 10

Classification and characteristics of composite materials - Types of fiber and resin materials, functions and their properties – Application of composite to aircraft structures-Micromechanics-Mechanics of materials, Elasticity approaches-Mass and volume fraction of fibers and resins-Effect of voids, Effect of temperature and moisture.

UNIT II MACROMECHANICS 10

Hooke’s law for orthotropic and anisotropic materials-Lamina stress-strain relations referred to natural axes and arbitrary axes.

UNIT III ANALYSIS OF LAMINATED COMPOSITES 10

Governing equations for anisotropic and orthotropic plates- Angle-ply and cross ply laminates-Analysis for simpler cases of composite plates and beams - Interlaminar stresses- Netting analysis.

UNIT IV MANUFACTURING & FABRICATION PROCESSES 8

Manufacture of glass, boron and carbon fibers-Manufacture of FRP components- Open mould and closed mould processes. Properties and functions of resins.

UNIT V FAILURE THEORY AND NDE 7

Failure criteria-Flexural rigidity of Sandwich beams and plates – composite repair- Ultra Sonic Technique - AE technique.

TOTAL: 45 PERIODS

OUTCOME:

Upon completion of the course, students will understand the fabrication, analysis and design of composite materials & structures.

REFERENCES

1. Autar K. Kaw, Mechanics of Composite Materials, CRC Press LLC, 1997
2. B.D. Agarwal and L.J. Broutman, “Analysis and Performance of fiber composites”, John-Wiley and Sons, 1990.
3. G.Lubin, “Hand Book on Fibre glass and advanced plastic composites”, Van Nostrand Co., New York, 1989.
4. J Prasad & CGK Nair Non-Destructive Testing and Evaluation of Material, Second Edition Paperback –ISBN-13: 978-0070707030,Amazon,2011
5. L.R. Calcote, “Analysis of laminated structures”, Van Nostrand Reinhold Co.,1989.
6. Michael Chun-Yung Niu Composite Airframe Structures Third Edition Conmilit Publishers 1997
7. P. Fordham, “Non-Destructive Testing Techniques” Business Publications, London, 1988.
8. R.M. Jones, “Mechanics of Composite Materials”, 2nd Edition, Taylor & Francis, 1999

AO5261 STRUCTURES LABORATORY L T P C
0 0 4 2

OBJECTIVES:

- To impart practical knowledge to the students on calibration of photoelastic materials determination of elastic constant for composite lamina, unsymmetrical bending of beams, determination of shear centre locations for closed and open sections and experimental studies.

LIST OF EXPERIMENTS

1. Constant strength Beams
2. Buckling of columns
3. Unsymmetrical Bending of Beams
4. Shear Centre Location for Open Section
5. Shear Centre Location for Closed Section
6. Flexibility Matrix for Cantilever Beam
7. Combined Loading
8. Calibration of Photo Elastic Materials
9. Stresses in Circular Disc Under Diametrical Compression – Photo Elastic Method
10. Vibration of Beams with Different Support Conditions
11. Fabrication and Determination of elastic constants of a composite laminate.
12. Wagner beam

NOTE: Any TEN experiments will be conducted out of 12.

TOTAL: 60 PERIODS

LABORATORY EQUIPMENTS REQUIREMENTS

1. Constant strength beam setup
2. Column setup
3. Unsymmetrical Bending setup
4. Experimental setup for location of shear centre (open & close section)
5. Cantilever beam setup
6. Experimental setup for bending and torsional loads
7. Diffuser transmission type polariscope with accessories

8. Experimental setup for vibration of beams
9. Universal Testing Machine
10. Wagner beam setup

OUTCOME:
Upon completion of the course, students will acquire experimental knowledge on the unsymmetrical bending of beams, finding the location of shear centre, obtaining the stresses in circular discs and beams using photoelastic techniques, calibration of photo – elastic materials.

AO5211 CFD / FEA LABORATORY L T P C
0 0 4 2

OUTCOME:
Upon completion of the course, students will be in a position to use Computational fluid dynamics software and Finite Element Analysis software for solving various aeronautical problems.

LIST OF EXPERIMENTS
1. Fatigue analysis of aircraft landing gear using FEM Software.
2. Rotor dynamic analysis of jet engine compressor blade using FEM Software
3. Rotor dynamic analysis of jet engine Turbine blade using FEM Software
4. Fracture Mechanics analysis of aircraft skin structure using FEM Software.
5. Random Vibration analysis of Aircraft Wing Structure.
6. Weight Optimization of Aircraft fuselage frame structure using FEM Software.
7. Stress Optimization of Aircraft fuselage frame structure using FEM Software.
8. Heat transfer analysis of Turbine blade using FEM Software.
9. Heat transfer analysis of rocket thrust chamber using FEM Software.
10. Prediction of Drag and lift on typical aircraft using CFD Software
11. Prediction of Drag and lift typical automobile using CFD Software
12. Flow simulation of propeller using CFD Software
13. Flow simulation of wind Turbine blade using CFD Software
14. Combustion simulation of mini jet engine using CFD Software
15. Combustion simulation of pulse jet engine using CFD Software
16. Acoustic study of jet engine using CFD Software.

NOTE: Any TEN experiments will be conducted out of 16.

TOTAL: 60 PERIODS

LABORATORY EQUIPMENTS REQUIREMENTS
1. Internal Server or Workstation
2. Computers
3. CAD Modelling Software
4. FEA Analysis Software
5. CFD Analysis Software

AO5001 BOUNDARY LAYER THEORY L T P C
3 0 0 3

OUTCOME:
Upon completion of the course, students will acquire knowledge on viscous fluid flow, development of boundary layer for 2D flows.

UNIT I VISCOUS FLOW EQUATIONS 9
Navier-Stokes Equations, Creeping motion, Couette flow, Poiseuille flow through ducts, Ekman drift.

UNIT II LAMINAR BOUNDARY LAYER 9

Development of boundary layer – Estimation of boundary layer thickness, Displacement thickness - Momentum and energy thicknesses for two dimensional flow – Two dimensional boundary layer equations – Similarity solutions - Blasius solution.

UNIT III TURBULENT BOUNDARY LAYER 9

Physical and mathematical description of turbulence, two-dimensional turbulent boundary layer equations, Velocity profiles – Inner, outer and overlap layers, Transition from laminar to turbulent boundary layers, turbulent boundary layer on a flat plate, mixing length hypothesis.

UNIT IV APPROXIMATE SOLUTION TO BOUNDARY LAYER EQUATIONS 9

Approximate integral methods, digital computer solutions – Von Karman – Polhausen method.

UNIT V THERMAL BOUNDARY LAYER 9

Introduction to thermal boundary layer – Heat transfer in boundary layer - Convective heat transfer, importance of non dimensional numbers – Prandtl number, Nusselt number, Lewis number etc.

TOTAL: 45 PERIODS

REFERENCES

1. A.J. Reynolds, "Turbulent flows in Engineering", John Wiley & Sons, 1980.
2. Frank White – Viscous Fluid flow – McGraw Hill, 1998
3. H. Schlichting, "Boundary Layer Theory", McGraw-Hill, New York, 1979.
4. Ronald L., Panton, "Incompressible fluid flow", John Wiley & Sons, 1984.
5. Tuncer Cebeci and Peter Bradshaw, "Momentum transfer in boundary layers", Hemisphere Publishing Corporation, 1977.

AO5002 AIRCRAFT DESIGN

L	T	P	C
3	0	0	3

OBJECTIVES:

- To impart knowledge to the students on various types of power plant types and also to expose them principles of aerodynamics and structural design aspects.

UNIT I REVIEW OF DEVELOPMENTS IN AVIATION 9

Categories and types of aircrafts – various configurations – Layouts and their relative merits – strength, stiffness, fail safe and fatigue requirements – Manoeuvering load factors – Gust and manoeuverability envelopes – Balancing and maneuvering loads on tail planes.

UNIT II POWER PLANT TYPES AND CHARACTERISTICS 9

Characteristics of different types of power plants – Propeller characteristics and selection – Relative merits of location of power plant.

UNIT III PRELIMINARY DESIGN 9

Selection of geometric and aerodynamic parameters – Weight estimation and balance diagram – Drag estimation of complete aircraft – Level flight, climb, takeoff and landing calculations – range and endurance – static and dynamic stability estimates – control requirements.

UNIT IV SPECIAL PROBLEMS 9

Layout peculiarities of subsonic and supersonic aircraft – optimization of wing loading to achieve desired performance – loads on undercarriages and design requirements.

UNIT V STRUCTURAL DESIGN 9

Estimation of loads on complete aircraft and components – Structural design of fuselage, wings and undercarriages, controls, connections and joints. Materials for modern aircraft – Methods of analysis, testing and fabrication.

PRACTICALS
Conceptual design of an aircraft for given specifications.

TOTAL: 45 PERIODS

OUTCOME:
Upon completion of the course, students will get the basic concept of aircraft design.

REFERENCES

1. A.A. Lebedenski, "Notes on airplane design", Part-I, I.I.Sc., Bangalore, 1971.
2. D.P. Raymer, "Aircraft conceptual design", AIAA Series, 1988.
3. E. Torenbeek, "Synthesis of Subsonic Airplane Design", Delft University Press, London, 1976.
4. E.F. Bruhn, "Analysis and Design of Flight Vehicle Structures", Tristate Offset Co., U.S.A., 1980.
5. G. Corning, "Supersonic & Subsonic Airplane Design", II Edition, Edwards Brothers Inc., Michigan, 1953.
6. H.N.Kota, Integrated design approach to Design fly by wire" Lecture notes Interline Pub. Bangalore, 1992.
7. Michael Niu , Michael C.Y. Niu ,Airframe Stress Analysis & Sizing 1st Edition 1997

AO5003	THEORY OF ELASTICITY	L T P C
		3 0 0 3

OBJECTIVE:

- To impart knowledge to students on basic governing equations of elasticity, solving of 2D problems in Cartesian and polar coordinates and also to introduce various theories and methods to solve torsion related problems.

UNIT I INTRODUCTION 6
Definition, notations and sign conventions for stress and strain – Stress - strain relations, Strain-displacement relations- Elastic constants.

UNIT II BASIC EQUATIONS OF ELASTICITY 10
Equations of equilibrium – Compatibility equations in strains and stresses –Boundary Conditions - Saint-Venant's principle - Stress ellipsoid – Stress invariants – Principal stresses in 2-D and 3-D.

UNIT III 2 - D PROBLEMS IN CARTESIAN COORDINATES 9
Plane stress and plain strain problems - Airy's stress function – Biharmonic equations – 2-D problems – Cantilever and simply supported beams.

UNIT IV 2 - D PROBLEMS IN POLAR COORDINATES 12
Equations of equilibrium – Strain – displacement relations – Stress – strain relations – Airy's stress function – Use of Dunder's table. - Axisymmetric problems - Bending of Curved Bars - Circular Discs and Cylinders – Rotating Discs and Cylinders - Kirsch, Boussinasque's and Michell's problems.

UNIT V TORSION 8
Coulomb's theory-Navier's theory-Saint Venant's Semi-Inverse method – Torsion of Circular, Elliptical and Triangular sections - Prandtl's theory-Membrane analogy.

TOTAL: 45 PERIODS

OUTCOME:
Upon completion of the course, students will understand the theoretical concepts of material behaviour with particular emphasis on their elasticity property.

REFERENCES

1. E. Sechler, "Elasticity in Engineering" John Wiley & Sons Inc., New York, 1980.
2. Enrico Volterra and Caines, J.H, Advanced strength of Materials, Prentice Hall,1991.

3. S.P. Timoshenko and J.N. Goodier, Theory of Elasticity, McGraw-Hill, 1985.
4. Ugural, A.C and Fenster, S.K, Advanced Strength and Applied Elasticity, Prentice hall, 2003
5. Wang, C.T. Applied elasticity, McGraw Hill 1993

AO5071 ROCKETRY AND SPACE MECHANICS L T P C
3 0 0 3

OBJECTIVES:
To familiarize the students on fundamental aspects of rocket propulsion, multi stating of rocket vehicle and spacecraft dynamics.

UNIT I ORBITAL MECHANICS 9
Description of solar system – Kepler's Laws of planetary motion – Newton's Law of Universal gravitation – Two body and Three-body problems – Jacobi's Integral, Librations points - Estimation of orbital and escape velocities

UNIT II SATELLITE DYNAMICS 9
Geosynchronous and geostationary satellites- factors determining life time of satellites – satellite perturbations – methods to calculate perturbations- Hohmann orbits – calculation of orbit parameters – Determination of satellite rectangular coordinates from orbital elements

UNIT III ROCKET MOTION 10
Principle of operation of rocket motor - thrust equation – one dimensional and two dimensional rocket motions in free space and homogeneous gravitational fields – Description of vertical, inclined and gravity turn trajectories determinations of range and altitude – simple approximations to burnout velocity.

UNIT IV ROCKET AERODYNAMICS 9
Description of various loads experienced by a rocket passing through atmosphere – drag estimation – wave drag, skin friction drag, form drag and base pressure drag – Boat-tailing in missiles – performance at various altitudes – conical and bell shaped nozzles – adapted nozzles – rocket dispersion – launching problems.

UNIT V STAGING AND CONTROL OF ROCKET VEHICLES 8
Need for multi-staging of rocket vehicles – multistage vehicle optimization – stage separation dynamics and separation techniques- aerodynamic and jet control methods of rocket vehicles - SITVC.

TOTAL: 45 PERIODS

OUTCOME:
Upon completion of the course, students will have an idea about solar system, basic concepts of orbital mechanics with particular emphasis on interplanetary trajectories.

REFERENCES
1. E.R. Parker, "Materials for Missiles and Spacecraft", McGraw-Hill Book Co., Inc., 1982.
2. G.P. Sutton, "Rocket Propulsion Elements", John Wiley & Sons Inc., New York, 5th Edition, 1986.
3. J.W. Cornelisse, "Rocket Propulsion and Space Dynamics", J.W. Freeman & Co., Ltd., London, 1982
4. Van de Kamp, "Elements of Astro-mechanics", Pitman Publishing Co., Ltd., London, 1980.

AO5004 **EXPERIMENTAL STRESS ANALYSIS** **L T P C**
3 0 0 3

OBJECTIVE:

- To make the students learn basic principles of operation, electrical resistance strain gauges, photoelasticity and interferometric techniques and non destructive methods.

UNIT I INTRODUCTION 8

Principle of measurements-Accuracy, sensitivity and range- Mechanical, Optical, Acoustical and Electrical extensometers.

UNIT II ELECTRICAL RESISTANCE STRAIN GAUGES 12

Principle of operation and requirements-Types and their uses-Materials for strain gauge-Calibration and temperature compensation-Cross sensitivity-Rosette analysis-Wheatstone bridge-Potentiometer circuits for static and dynamic strain measurements-Strain indicators- Application of strain gauges to wind tunnel balance.

UNIT III PRINCIPLES OF PHOTOELASTICITY 9

Two dimensional photo elasticity-Concepts of photoelastic effects-Photoelastic materials-Stress optic law-Plane polariscope–Circular polariscope-Transmission and Reflection type-Effect of stressed model in Plane and Circular polariscope. Interpretation of fringe pattern Isoclinics and Isochromatics.-Fringe sharpening and Fringe multiplication techniques-Compensation and separation techniques-Introduction to three dimensional photoelasticity.

UNIT IV PHOTOELASTICITY AND INTERFEROMETRY TECHNIQUES 9

Fringe sharpening and Fringe multiplication techniques-Compensation and separation techniques-Calibration methods –Photo elastic materials. Introduction to three dimensional photoelasticity. Moire fringes – Laser holography – Grid methods-Stress coat

UNIT V NON DESTRUCTIVE TECHNIQUES 7

Radiography- Ultrasonics- Magnetic particle inspection- Fluorescent penetrant technique-Eddy current testing– thermography– MICRO FOCUS CT scan.

TOTAL: 45 PERIODS

OUTCOME:

Upon completion of the course, students will be able to appreciate use of strain gauges and its principles, principle of photoelasticity and its use, NDT techniques.

REFERENCES

1. A.J. Durelli and V.J. Parks, “Moire Analysis of Strain”, Prentice Hall Inc., Englewood Cliffs, New Jersey, 1980.
2. G.S. Holister, “Experimental Stress Analysis, Principles and Methods”, Cambridge University Press, 1987.
3. J Prasad & CGK Nair Non-Destructive Testing and Evaluation of Material, Second Edition Paperback –ISBN-13: 978-0070707030,Amazon,2011
4. J.W. Dally and M.F. Riley, “Experimental Stress Analysis”, McGraw-Hill Book Co., New York, 1988.
5. M. Hetenyi, “Handbook of Experimental Stress Analysis”, John Wiley & Sons Inc., New York, 1980.
6. P. Fordham, “Non-Destructive Testing Techniques” Business Publications, London, 1988.
7. Srinath,L.S., Raghava,M.R., Lingaiah,K. Gargesha,G.,Pant B. and Ramachandra,K. – Experimental Stress Analysis, Tata McGraw Hill, New Delhi, 1984
8. U. C. Jindal Experimental Stress Analysis, Pearson India, ISBN: 9789332503533, 2012

AO5005 THEORY OF PLATES AND SHELLS **L T P C**
3 0 0 3

UNIT I CLASSICAL PLATE THEORY 8
Classical Plate Theory – Assumptions – Differential Equations – Boundary Conditions.

UNIT II PLATES OF VARIOUS SHAPES 10
Navier's Method of Solution for Simply Supported Rectangular Plates – Levy's Method of Solution for Rectangular Plates under Different Boundary Conditions – Circular plates.

UNIT III EIGEN VALUE ANALYSIS 8
Stability and Free Vibration Analysis of Rectangular Plates with various end conditions.

UNIT IV APPROXIMATE METHODS 10
Rayleigh – Ritz, Galerkin Methods– Finite Difference Method – Application to Rectangular Plates for Static, Free Vibration and Stability Analysis.

UNIT V SHELLS 9
Basic Concepts of Shell Type of Structures – Membrane and Bending Theories for Circular Cylindrical Shells.

TOTAL: 45 PERIODS

OUTCOME:
Upon completion of the course, students will get knowledge on the behaviour of plates and shells with different geometry under various types of loads

REFERENCES

1. Flugge, W. Stresses in Shells, Springer – Verlag, 1985.
2. Harry Kraus, 'Thin Elastic Shells', John Wiley and Sons, 1987.
3. T.K.Varadan & K. Bhaskar, "Análysis of plates – Theory and problems", Narosha Publishing Co., 1999.
4. Timoshenko, S.P. and Gere, J.M., Theory of Elastic Stability, McGraw Hill Book Co. 1986.
5. Timoshenko, S.P. Winowsky. S., and Kreger, Theory of Plates and Shells, McGraw Hill Book Co., 1990.

AO5006 HIGH TEMPERATURE PROBLEMS IN STRUCTURES **L T P C**
3 0 0 3

UNIT I TEMPERATURE EQUATIONS & AERODYNAMIC HEATING 9
Basics of conduction, radiation and convection – Fourier's equation – Boundary and initial conditions – One-dimensional problem formulations – Methods and Solutions. Heat balance equation for idealised structures – Adiabatic temperature – Variations – Evaluation of transient temperature.

UNIT II THERMAL STRESS ANALYSIS 9
Thermal stresses and strains – Equations of equilibrium – Boundary conditions – Thermoelasticity – Two dimensional problems and solutions – Airy stress function and applications.

UNIT III THERMAL STRESS IN BEAMS, TRUSSES AND THIN CYLINDERS 9
Analysis of bar, plane truss and beam under mechanical loads and temperature. Thermal stress analysis of thin cylinder.

UNIT IV THERMAL STRESSES IN PLATES 9
Membrane thermal stresses –Rectangular plates – Circular plates – Thick plates with temperature varying along thickness.

UNIT V SPECIAL TOPICS & MATERIALS 9

Thermal bucking – Analysis including material properties variation with temperature.

TOTAL: 45 PERIODS

OUTCOME:

Upon completion of the course, students will learn the analysis of bar, plane truss and beam under mechanical and thermal loads.

REFERENCES

1. A.B. Bruno and H.W. Jerome, “Theory of Thermal Stresses”, John Wiley & Sons Inc., New York, 1980.
2. D.J. Johns, “Thermal Stress Analysis”, Pergamon Press, Oxford, 1985.
3. N.J. Hoff, “High Temperature effects in Aircraft Structures”, John Wiley & Sons Inc., London, 1986.

AO5074 FATIGUE AND FRACTURE MECHANICS L T P C
3 0 0 3

OBJECTIVE:

- To make the students learn about fundamentals of fatigue & fracture mechanics, statistical aspects of fatigue behaviour & fatigue design and testing of aerospace structures.

UNIT I FATIGUE OF STRUCTURES 10

S.N. curves – Endurance limit – Effect of mean stress – Goodman, Gerber and Soderberg relations and diagrams – Notches and stress concentrations – Neuber’s stress concentration factors – plastic stress concentration factors – Notched S-N curves.

UNIT II STATISTICAL ASPECTS OF FATIGUE BEHAVIOUR 8

Low cycle and high cycle fatigue – Coffin-Manson’s relation – Transition life – Cyclic Strain hardening and softening – Analysis of load histories – Cycle counting techniques – Cumulative damage – Miner’s theory – other theories.

UNIT III PHYSICAL ASPECTS OF FATIGUE 5

Phase in fatigue life – Crack initiation – Crack growth – Final fracture – Dislocations – Fatigue fracture surfaces.

UNIT IV FRACTURE MECHANICS 15

Strength of cracked bodies – potential energy and surface energy – Griffith’s theory – Irwin – Orwin extension of Griffith’s theory to ductile materials – Stress analysis of cracked bodies – Effect of thickness on fracture toughness – Stress intensity factors for typical geometries.

UNIT V FATIGUE DESIGN AND TESTING 7

Safe life and fail safe design philosophies – Importance of Fracture Mechanics in aerospace structure – Application to composite materials and structures.

TOTAL: 45 PERIODS

OUTCOME:

Upon completion of the course, students will learn about fracture behaviour, fatigue design and testing of structures.

REFERENCES

1. C.G.Sih, “Mechanics of Fracture”, Vol.1 Sijthoff and Noordhoff International Publishing Co., Netherland, 1989.
2. D.Brock, “Elementary Engineering Fracture Mechanics”, Noordhoff International Publishing Co., London, 1994.
3. J.F.Knott, “Fundamentals of Fracture Mechanics”, Butterworth & Co., (Publishers) Ltd., London, 1983.
4. W.Barrois and L.Ripley, “Fatigue of Aircraft Structures”, Pergamon Press, Oxford, 1983.

AO5007 INDUSTRIAL AERODYNAMICS **L T P C**
3 0 0 3

UNIT I ATMOSPHERE 9

Types of winds, Causes of variation of winds, Atmospheric boundary layer, Effect of terrain on gradient height, Structure of turbulent flows.

UNIT II WIND ENERGY COLLECTORS 9

Horizontal axis and vertical axis machines, Power coefficient, Betz coefficient by momentum theory.

UNIT III VEHICLE AERODYNAMICS 9

Power requirements and drag coefficients of automobiles, Effects of cut back angle, Aerodynamics of trains and Hovercraft.

UNIT IV BUILDING AERODYNAMICS 9

Pressure distribution on low rise buildings, wind forces on buildings. Environmental winds in city blocks, Special problems of tall buildings, Building codes, Building ventilation and architectural aerodynamics.

UNIT V FLOW INDUCED VIBRATIONS 9

Effects of Reynolds number on wake formation of bluff shapes, Vortex induced vibrations, Galloping and stall flutter.

TOTAL: 45 PERIODS

OUTCOME:

Upon completion of the course, students will learn about non-aeronautical uses of aerodynamics such as road vehicle, building aerodynamics and problems of flow induced vibrations.

REFERENCES

1. M.Sovran (Ed), “Aerodynamics and drag mechanisms of bluff bodies and road vehicles”, Plenum press, New York, 1978.
2. N.G. Calvent, “Wind Power Principles”, Charles Griffin & Co., London, 1979.
3. P. Sachs, “Winds forces in engineering”, Pergamon Press, 1978.
4. R.D. Blevins, “Flow induced vibrations”, Van Nostrand, 1990.

AO5091 HYPERSONIC AERODYNAMICS **L T P C**
3 0 0 3

OBJECTIVES:

- To make students learn the peculiar hypersonic speed flow characteristics pertaining to flight vehicles and the approximate solution methods for hypersonic flows. The objective is also to impart knowledge on hypersonic viscous interactions and their effect on aerodynamic heating.

UNIT I BASICS OF HYPERSONIC AERODYNAMICS 8

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

UNIT II SURFACE INCLINATION METHODS FOR HYPERSONIC INVISCID FLOWS 9

Local surface inclination methods – modified Newtonian Law – Newtonian theory – tangent wedge or tangent cone and shock expansion methods – Calculation of surface flow properties

UNIT III APPROXIMATE METHODS FOR INVISCID HYPERSONIC FLOWS` 9

Approximate methods hypersonic small disturbance equation and theory – thin shock layer theory – blast wave theory - entropy effects - rotational method of characteristics - hypersonic shock wave shapes and correlations.

UNIT IV VISCOUS HYPERSONIC FLOW THEORY 10

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

UNIT V VISCOUS INTERACTIONS IN HYPERSONIC FLOWS 9

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

TOTAL: 45 PERIODS

OUTCOME:

Upon completion of the course, students will learn basics of hypersonic flow, shock wave - boundary layer interaction and hypersonic aerodynamic heating.

REFERENCES

1. John D. Anderson, Jr, Hypersonic and High Temperature Gas Dynamics, McGraw-Hill Series, New York, 1996.
2. John T. Bertin, Hypersonic Aerothermodynamics, 1994 AIAA Inc., Washington D.
3. John.D.Anderson, Jr., Modern Compressible Flow with Historical perspective Hypersonic Series.
4. William H. Heiser and David T. Pratt, Hypersonic Air Breathing propulsion, AIAA Education Series.

AO5072 COMPUTATIONAL HEAT TRANSFER L T P C
3 0 0 3

OBJECTIVES:

- To make the students learn to solve conductive, transient conductive, convective, radiative heat transfer problems using computational methods.

UNIT I INTRODUCTION 9

Finite Difference Method-Introduction-Taylor's series expansion - Discretisation Methods Forward, backward and central differencing scheme for Ist order and second order Derivatives – Types of partial differential equations-Types of errors. Solution to algebraic equation-Direct Method and Indirect Method-Types of boundary condition.
FDM - FEM - FVM.

UNIT II CONDUCTIVE HEAT TRANSFER 9

General 3D-heat conduction equation in Cartesian, cylindrical and spherical coordinates.
Computation (FDM) of One – dimensional steady state heat conduction –with Heat generation-without Heat generation- 2D-heat conduction problem with different boundary conditions-Numerical treatment for extended surfaces. Numerical treatment for 3D- Heat conduction.
Numerical treatment to 1D-steady heat conduction using FEM.

UNIT III TRANSIENT HEAT CONDUCTION 9

Introduction to Implicit, explicit Schemes and crank-Nicolson Schemes Computation(FDM) of One –dimensional un-steady heat conduction –with heat Generation-without Heat generation - 2D-transient heat conduction problem with different boundary conditions using Implicit, explicit Schemes. Importance of Courant number. Analysis for I-D,2-D transient heat Conduction problems.

UNIT IV CONVECTIVE HEAT TRANSFER 9

Convection- Numerical treatment(FDM) of steady and unsteady 1-D and 2-d heat convection-diffusion steady-unsteady problems- Computation of thermal and Velocity boundary layer flows. Upwind scheme. Stream function-vorticity approach-Creeping flow.

UNIT V RADIATIVE HEAT TRANSFER 9

Radiation fundamentals-Shape factor calculation-Radiosity method- Absorption Method-Montacalro method-Introduction to Finite Volume Method- Numerical treatment of radiation enclosures using finite Volume method. Developing a numerical code for 1D, 2D heat transfer problems.

TOTAL: 45 PERIODS

OUTCOME:

Upon completion of the course, students will learn the concepts of computation applicable to heat transfer for practical applications.

REFERENCES

1. C.Y.Chow, "Introduction to Computational Fluid Dynamics", John Wiley, 1979.
2. J.P. Holman, "Heat Transfer", McGraw-Hill Book Co., Inc., New York, 6^{th} Edition, 1991.
3. John D. Anderson, JR" Computational Fluid Dynamics", McGraw-Hill Book Co., Inc., New York, 1995.
4. John H. Lienhard, "A Heat Transfer Text Book", Prentice Hall Inc., 1981.
5. Pletcher and Tennahils " Computational Heat Trasnfer"…..
6. S.C. Sachdeva, "Fundamentals of Engineering Heat & Mass Transfer", Wiley Eastern Ltd., New Delhi, 1981.
7. T.J. Chung, Computational Fluid Dynamics, Cambridge University Press, 2002
8. Yunus A. Cengel, Heat Transfer – A Practical Approach Tata McGraw Hill Edition, 2003.

AO5008	WIND POWER ENGINEERING	L T P C
		3 0 0 3

UNIT I INTRODUCTION TO WIND ENERGY 8

Background,Motivations, and Constraints, Historical perspective, Modern wind turbines, Components and geometry, Power characteristics.

UNIT II WIND CHARACTERISTICS AND RESOURCES 8

General characteristics of the wind resource, Atmospheric boundarylayer characteristics, Wind data analysis and resource estimation, Wind turbine energy production estimates using statistical techniques

UNIT III AERODYNAMICS OF WIND TURBINES 12

Overview , 1-D Momentum theory,Ideal horizontal axis wind turbine with wake rotation, Airfoils and aerodynamic concepts -Momentum theory and blade element theory General rotor blade shape performance prediction - Wind turbine rotor dynamics

UNIT IV WIND TURBINE DESIGN & CONTROL 9

Brief design overview – Introduction -Wind turbine control systems -Typical grid-connected turbine operation -Basic concepts of electricpower- Power transformers -Electrical machines

UNIT V ENVIRONMENTAL AND SITE ASPECTS 8

Overview- Wind turbine siting - Installation and operation- Wind farms- Overview of wind energy economics-Electromagnetic interference-noise-Land use impacts - Safety

TOTAL: 45 PERIODS

OUTCOME:
Upon completion of the course, students will learn about aerodynamics, design and control of wind turbines.

REFERENCES:

1. Emil Simiu & Robert H Scanlan, Wind effects on structures - fundamentals and applications to design, John Wiley & Sons Inc New York, 1996.
2. IS: 875 (1987) Part III Wind loads, Indian Standards for Building codes.
3. N J Cook, Design Guides to wind loading of buildings structures Part I & II, Butterworths, London, 1985
4. Tom Lawson Building Aerodynamics Imperial College Press London, 2001

AO5073 ADVANCED PROPULSION SYSTEMS **L T P C**
3 0 0 3

OBJECTIVES:
- To familiarize the students on advanced air breathing propulsion systems like air augmented rockets, scramjets and also to introduce the students various technical details and operating principles of nuclear and electric propulsion.

UNIT I THERMODYNAMIC CYCLE ANALYSIS OF AIR-BREATHING PROPULSION SYSTEMS 8
Air breathing propulsion systems like Turbojet, turboprop, ducted fan, Ramjet and Air augmented rockets – Thermodynamic cycles – Pulse propulsion – Combustion process in pulse jet engines – inlet charging process – Subcritical, Critical and Supercritical charging.

UNIT II RAMJETS AND AIR AUGMENTED ROCKETS 8
Preliminary performance calculations – Diffuser design with and without spike, Supersonic inlets – combustor and nozzle design – integral Ram rocket.

UNIT III SCRAMJET PROPULSION SYSTEM 12
Fundamental considerations of hypersonic air breathing vehicles – Preliminary concepts in engine airframe integration – calculation of propulsion flow path – flowpath integration – Various types of supersonic combustors – fundamental requirements of supersonic combustors – Mixing of fuel jets in supersonic cross flow – performance estimation of supersonic combustors.

UNIT IV NUCLEAR PROPULSION 9
Nuclear rocket engine design and performance – nuclear rocket reactors – nuclear rocket nozzles – nuclear rocket engine control – radioisotope propulsion – basic thruster configurations – thruster technology – heat source development – nozzle development – nozzle performance of radiosotope propulsion systems.

UNIT V ELECTRIC AND ION PROPULSION 8
Basic concepts in electric propulsion – power requirements and rocket efficiency – classification of thrusters – electrostatic thrusters – plasma thruster of the art and future trends – Fundamentals of ion propulsion – performance analysis – ion rocket engine.

TOTAL: 45 PERIODS

OUTCOME:
Upon completion of the course, students will learn in detail about gas turbines, ramjet, fundamentals of rocket propulsion and chemical rockets.

REFERENCES
1. Cumpsty, Jet propulsion, Cambridge University Press, 2003.
2. Fortescue and Stark, Spacecraft Systems Engineering, 1999.
3. G.P. Sutton, "Rocket Propulsion Elements", John Wiley & Sons Inc., New York,1998.
4. William H. Heiser and David T. Pratt, Hypersonic Airbreathing propulsion, AIAA Education Series, 2001.

IL5091 **DATA ANALYTICS** **L T P C**
3 0 0 3

OBJECTIVES:
The Student should be made to:
- Be exposed to big data
- Learn the different ways of Data Analysis
- Be familiar with data streams
- Learn the mining and clustering
- Be familiar with the visualization

UNIT I INTRODUCTION TO BIG DATA 8
Introduction to Big Data Platform – Challenges of conventional systems - Web data – Evolution of Analytic scalability, analytic processes and tools, Analysis vs reporting - Modern data analytic tools, Stastical concepts: Sampling distributions, resampling, statistical inference, prediction error.

UNIT II DATA ANALYSIS 12
Regression modeling, Multivariate analysis, Bayesian modeling, inference and Bayesian networks, Support vector and kernel methods, Analysis of time series: linear systems analysis, nonlinear dynamics - Rule induction - Neural networks: learning and generalization, competitive learning, principal component analysis and neural networks; Fuzzy logic: extracting fuzzy models from data, fuzzy decision trees, Stochastic search methods.

UNIT III MINING DATA STREAMS 8
Introduction to Streams Concepts – Stream data model and architecture - Stream Computing, Sampling data in a stream – Filtering streams – Counting distinct elements in a stream – Estimating moments – Counting oneness in a window – Decaying window - Realtime Analytics Platform(RTAP) applications - case studies - real time sentiment analysis, stock market predictions.

UNIT IV FREQUENT ITEMSETS AND CLUSTERING 9
Mining Frequent itemsets - Market based model – Apriori Algorithm – Handling large data sets in Main memory – Limited Pass algorithm – Counting frequent itemsets in a stream – Clustering Techniques – Hierarchical – K- Means – Clustering high dimensional data – CLIQUE and PROCLUS – Frequent pattern based clustering methods – Clustering in non-euclidean space – Clustering for streams and Parallelism.

UNIT V FRAMEWORKS AND VISUALIZATION 8
MapReduce – Hadoop, Hive, MapR – Sharding – NoSQL Databases - S3 - Hadoop Distributed file systems – Visualizations - Visual data analysis techniques, interaction techniques; Systems and applications:

TOTAL : 45 PERIODS

OUTCOMES:

The student should be made to:

- Apply the statistical analysis methods.
- Compare and contrast various soft computing frameworks.
- Design distributed file systems.
- Apply Stream data model.
- Use Visualisation techniques

REFERENCES:

1. Anand Rajaraman and Jeffrey David Ullman, Mining of Massive Datasets, Cambridge University Press, 2012.
2. Bill Franks, Taming the Big Data Tidal Wave: Finding Opportunities in Huge Data Streams with advanced analystics, John Wiley & sons, 2012.
3. Glenn J. Myatt, Making Sense of Data, John Wiley & Sons, 2007 Pete Warden, Big Data Glossary, O"Reilly, 2011.
4. Jiawei Han, Micheline Kamber “Data Mining Concepts and Techniques”, Second Edition, Elsevier, Reprinted 2008.
5. Michael Berthold, David J. Hand, Intelligent Data Analysis, Springer, 2007.

AO5010	**AERO ELASTICITY**	**L T P C**
		3 0 0 3

OBJECTIVES:

- To make the students understand aero elastic phenomena, flutter and to make them to solve steady state aero elastic problems.

UNIT I AEROELASTIC PHENOMENA 6

Stability versus response problems – The aero-elastic triangle of forces – Aeroelasticity in Aircraft Design – Prevention of aeroelastic instabilities. Influence and stiffness co-efficients. Flexure – torsional oscillations of beam – Differential equation of motion of beam.

UNIT II DIVERGENCE OF A LIFTING SURFACE 10

Simple two dimensional idealisations-Strip theory – Integral equation of the second kind – Exact solutions for simple rectangular wings – ‘Semirigid’ assumption and approximate solutions – Generalised coordinates – Successive approximations – Numerical approximations using matrix equations.

UNIT III STEADY STATE AEROLASTIC PROBLEMS 9

Loss and reversal of aileron control – Critical aileron reversal speed – Aileron efficiency – Semi rigid theory and successive approximations – Lift distribution – Rigid and elastic wings. Tail efficiency. Effect of elastic deformation on static longitudinal stability.

UNIT IV FLUTTER PHENOMENON 14

Non-dimensional parameters – Stiffness criteria – Dynamic mass balancing – Dimensional similarity. Flutter analysis – Two dimensional thin airfoils in steady incompressible flow – Quasisteady aerodynamic derivatives. Galerkin method for critical flutter speed – Stability of disturbed motion – Solution of the flutter determinant – Methods of determining the critical flutter speeds – Flutter prevention and control.

UNIT V EXAMPLES OF AEROELASTIC PROBLEMS 6

Galloping of transmission lines and Flow induced vibrations of transmission lines, tall slender structures and suspension bridges, VIV.

TOTAL: 45 PERIODS

OUTCOME:
Upon completion of the course, Students can understand the theoretical concepts of material behaviour with particular emphasis on their elasticity property.

REFERENCES

1. E.G. Broadbent, “Elementary Theory of Aeroelasticity”, Bun Hill Publications Ltd., 1986.
2. R.D.Blevins, “Flow Induced Vibrations”, Krieger Pub Co., 2001
3. R.H. Scanlan and R.Rosenbaum, “Introduction to the study of Aircraft Vibration and Flutter”, Macmillan Co., New York, 1981.
4. R.L. Bisplinghoff, H.Ashley, and R.L. Halfmann, “Aeroelasticity”, II Edition Addison Wesley Publishing Co., Inc., 1996.
5. Y.C. Fung, “An Introduction to the Theory of Aeroelasticity”, John Wiley & Sons Inc., New York, 2008.

EY5092 DESIGN AND ANALYSIS OF TURBOMACHINES **L T P C**
3 0 0 3

OBJECTIVES:
- To design and analyse the performance of Turbo machines for engineering applications
- To understand the energy transfer process in Turbomachines and governing equations of various forms.
- To understand the structural and functional aspects of major components of Turbomachines.
- To design various Turbomachines for power plant and aircraft applications

UNIT I INTRODUCTION 12
Basics of isentropic flow – static and stagnation properties – diffuser and nozzle configurations - area ratio – mass flow rate – critical properties. Energy transfer between fluid and rotor velocity triangles for a generalized turbomachines - velocity diagrams. Euler's equation for turbomachines and its different forms. Degree of reaction in turbo-machines – various efficiencies – isentropic, mechanical, thermal, overall and polytropic

UNIT II CENTRIFUGAL AND AXIAL FLOW COMPRESSORS 9
Centrifugal compressor - configuration and working – slip factor - work input factor – ideal and actual work - pressure coefficient - pressure ratio. Axial flow compressor – geometry and working – velocity diagrams – ideal and actual work – stage pressure ratio - free vortex theory – performance curves and losses

UNIT III COMBUSTION CHAMBER 9
Basics of combustion. Structure and working of combustion chamber – combustion chamber arrangements - flame stability – fuel injection nozzles. Flame stabilization - cooling of combustion chamber

UNIT IV AXIAL AND RADIAL FLOW TURBINES 9
Elementary theory of axial flow turbines - stage parameters- multi-staging - stage loading and flow coefficients. Degree of reaction - stage temperature and pressure ratios – single and twin spool arrangements – performance. Matching of components. Blade Cooling. Radial flow turbines.

UNIT V GAS TURBINE AND JET ENGINE CYCLES 9
Gas turbine cycle analysis – simple and actual. Reheated, Regenerative and Intercooled cycles for power plants. Working of Turbojet, Turbofan, Turboprop, Ramjet, Scarmjet and Pulsejet Engines and cycle analysis – thrust, specific impulse, specific fuel consumption, thermal and propulsive efficiencies.

TOTAL: 45 PERIODS

OUTCOMES:
When a student completes this subject, he / she can

- Understand the design principles of the turbomachines
- Analyse the turbomachines to improve and optimize its performance

REFERENCES:

1. Austin H. Chruch, Centrifugal pumps and blowers, John wiley and Sons, 1980.
2. Cohen H., Rogers, G F C. and Saravanmotto H I H., Gas Turbine Theory-5th Edition, John Wiely, 2001.
3. Csanady G.T., Theory of Turbo machines, McGraw Hill, 1964.
4. Ganesan V., Gas Turbines, Tata McGrawHill, 2011.
5. Hill P G. and Peterson C R., Mechanics and Thermodynamics of Propulsion, Addition-Wesley, 1970.
6. Khajuria P.R. and Dubey S.P., Gas Turbines and Propulsive Systems, Dhanpat Rai Publications, 2003.
7. Mattingly J D., Elements of Gas turbine Propulsion-1st Edition, McGraw Hill, 1997.

AO5011 HELICOPTER AERODYNAMICS **L T P C**
3 0 0 3

OBJECTIVES:

- To impart knowledge to the students and fundamental aspects of helicopter aerodynamics, performance of helicopters, stability and control aspects and also to expose them basic and aerodynamic design aspects.

UNIT I INTRODUCTION 7
Types of rotorcraft – autogyro, gyrodyne, helicopter, Main rotor system – articulated, semi rigid, rigid rotors, Collective pitch control, cyclic pitch control, anti torque pedals.

UNIT II HELICOPTER AERODYNAMICS 12
Momentum / actuator disc theory, Blade element theory, combined blade element and momentum theory, vortex theory, rotor in hover, rotor model with cylindrical wake and constant circulation along blade, free wake model, Constant chord and ideal twist rotors, Lateral flapping, Coriolis forces, reaction torque, compressibility effects, Ground effect.

UNIT III PERFORMANCE 9
Hover and vertical flight, forward level flight, Climb in forward flight, optimum speeds, Maximum level speed, rotor limits envelope – performance curves with effects of altitude

UNIT IV STABILITY AND CONTROL 9
Helicopter Trim, Static stability – Incidence disturbance, forward speed disturbance, angular velocity disturbance, yawing disturbance, Dynamic Stability.

UNIT V AERODYNAMIC DESIGN 8
Blade section design, Blade tip shapes, Drag estimation – Rear fuselage upsweep,

TOTAL: 45 PERIODS

OUTCOME:
Upon completion of the course, students will learn about the basic ideas of evolution, performance and associated stability problems of helicopter.

REFERENCES
1. A. Gessow and G.C.Meyers, “Aerodynamics of the Helicopter”, Macmillan and Co., New York, 1982.
2. J. Seddon, “ Basic Helicopter Aerodynamics”, AIAA Education series, Blackwell scientific publications, U.K, 1990.
3. John Fay, “The Helicopter”, Himalayan Books, New Delhi, 1995.
4. Lalit Gupta, “Helicopter Engineering”, Himalayan Books, New Delhi, 1996.
5. Lecture Notes on “Helicopter Technology”, Department of Aerospace Engineering, IIT –Kanpur and Rotary Wing aircraft R&D center, HAL, Bangalore, 1998.

AO5012 EXPERIMENTAL AERODYNAMICS **L T P C**
3 0 0 3

OBJECTIVES:
- To make the students learn basic wind tunnel measurements and flow visualization methods, flow measurement variables and data acquisition method pertaining to experiments in aerodynamics.

UNIT I BASIC MEASUREMENTS IN FLUID MECHANICS 8
Objective of experimental studies – Fluid mechanics measurements – Properties of fluids – Measuring instruments – Performance terms associated with measurement systems – Direct measurements - Analogue methods – Flow visualization –Components of measuring systems – Importance of model studies - Experiments on Taylor-Proudman theorem and Ekman layer – Measurements in boundary layers -

UNIT II WIND TUNNEL MEASEUREMENTS 8
Characteristic features, operation and performance of low speed, transonic, supersonic and special tunnels - Power losses in a wind tunnel – Instrumentation and calibration of wind tunnels – Turbulence- Wind tunnel balance – Principle and application and uses – Balance calibration.

UNIT III FLOW VISUALIZATION AND ANALOGUE METHODS 10
Visualization techniques – Smoke tunnel – Hele-Shaw apparatus - Interferometer – Fringe-Displacement method – Shadowgraph - Schlieren system – Background Oriented Schliren (BOS) System - Hydraulic analogy – Hydraulic jumps – Electrolytic tank

UNIT IV PRESSURE, VELOCITY AND TEMPERATURE MEASUREMENTS 10
Pitot-Static tube characteristics - Velocity measurements - Hot-wire anemometry – Constant current and Constant temperature Hot-Wire anemometer – Hot-film anemometry – Laser Doppler Velocimetry (LDV) – Particle Image Velocimetry (PIV) – Pressure Sensitive Paints - Pressure measurement techniques - Pressure transducers – Temperature measurements.

UNIT V DATA ACQUISITION SYSTEMS AND UNCERTAINTY ANALYSIS 9
Data acquisition and processing – Signal conditioning - Estimation of measurement errors – Uncertainty calculation - Uses of uncertainty analysis.

TOTAL: 45 PERIODS

OUTCOME:
Upon completion of the course, students will learn about the measurement of flow properties in wind tunnels and their associated instrumentation.

REFERENCES
1. Rathakrishnan, E., “Instrumentation, Measurements, and Experiments in Fluids,”CRC Press – Taylor & Francis, 2007.
2. Robert B Northrop, “Introduction to Instrumentation and Measurements”, Second Edition, CRC Press, Taylor & Francis, 2006.

AO5013 HIGH TEMPERATURE GAS DYNAMICS

L	T	P	C
3	0	0	3

OBJECTIVES:

- To make the students learn the kinetic theory of hypersonic flows and statistical thermodynamic aspects of flows at very high temperatures and also to make them familiarize the calculations transport properties of gases high temperature.

UNIT I INTRODUCTION 8

Nature of high temperature flows – Chemical effects in air – Real perfect gases – Gibb's free energy and entropy by chemical and non equilibrium – Chemically reacting mixtures and boundary layers.

UNIT II STATISTICAL THERMODYNAMICS 8

Introduction to statistical thermodynamics – Relevance to hypersonic flow - Microscopic description of gases – Boltzman distribution – Cartesian function

UNIT III KINETIC THEORY AND HYPERSONIC FLOWS 9

Chemical equilibrium calculation of equilibrium composition of high temperature air – equilibrium properties of high temperature air – collision frequency and mean free path – velocity and speed distribution functions.

UNIT IV INVISCID HIGH TEMPERATURE FLOWS 10

Equilibrium and non – equilibrium flows – governing equations for inviscid high temperature equilibrium flows – equilibrium normal and oblique shock wave flows – frozen and equilibrium flows – equilibrium conical and blunt body flows – governing equations for non equilibrium inviscid flows.

UNIT V TRANSPORT PROPERTIES IN HIGH TEMPERATURE GASES 10

Transport coefficients – mechanisms of diffusion – total thermal conductivity – transport characteristics for high temperature air – radiative transparent gases – radiative transfer equation for transport, absorbing and emitting and absorbing gases.

TOTAL: 45 PERIODS

OUTCOME:

Upon completion of the course, students will learn statistical thermodynamics and the transport properties of high temperature gases.

REFERENCES

1. John D. Anderson, Jr., Hypersonic and High Temperature Gas Dynamics, McGraw-Hill Series, New York, 1996.
2. John D. Anderson, Jr., Modern Compressible Flow with Historical perspective, McGraw-Hill Series, New York, 1996.
3. John T. Bertin, Hypersonic Aerothermodynamics publishers - AIAA Inc., Washington, D.C.,1994.
4. T.K.Bose, High Temperature Gas Dynamics,
5. William H. Heiser and David T. Pratt, Hypersonic Air breathing propulsion, AIAA Education Series.

AO5075 HIGH SPEED JET FLOWS L T P C
3 0 0 3

OBJECTIVES:

- To make the students learn about various jet control methods, jet acoustics aspects and free shear layer flow theory pertaining to turbulent jets with high speed.

UNIT I INTRODUCTION 9

Types of nozzles – over expanded and underexpanded flows - Isentropic flow through nozzles– Interaction of nozzle flows over adjacent surfaces – Mach disk - Jet flow – types - Numerical problems.

UNIT II COMPRESSIBLE FLOW THEORY 9

One-dimensional compressible fluid flow – flow through variable area passage – nozzles and diffusers – normal and oblique shock waves and calculation of flow and fluid properties across the shocks and expansion fans. Interaction of shocks with solid and fluid surface.

UNIT III JET CONTROL 9

Types of jet control - single jet, multi jet, co-flow jet, parallel flow jet. Subsonic jets- Mathematical treatment of jet profiles- Theory of Turbulent jets- Mean velocity and mean temperature- Turbulence characteristics of free jets- Mixing length- Experimental methods for studying jets and the Techniques used for analysis- Expansion levels of jets- Overexpanded, Correctly expanded, Underexpanded jets - Control of jets. Centre line decay, Mach number Profile, Iso-Mach (or iso-baric) contours, Shock cell structure in underexpanded and overexpanded jets, Mach discs.

UNIT IV BOUNDARY LAYER CONCEPT 9

Boundary Layer – displacement and momentum thickness- laminar and turbulent boundary layers over flat plates – velocity distribution in turbulent flows over smooth and rough boundaries- laminar sublayer. Shock-boundary layer interactions.

UNIT V JET ACOUSTICS 9

Introduction to Acoustic – Types of noise – Source of generation- Traveling wave solution-standing wave solution – multi-dimensional acoustics -Noise suppression techniques– applications to problems.

TOTAL: 45 PERIODS

OUTCOME:

Upon completion of this course, students will be able to understand various jet control methods, jet acoustics aspects and free shear layer flow theory pertaining to turbulent jets with high speed.

REFERENCES

1. Ethirajan Rathakrishnan, "Applied Gas Dynamics", John Wiley, NY,, 2010.
2. Liepmann and Roshko, "Elements of Gas Dynamics", John Wiley, NY, 1963.
3. Rathakrishnan E., "Gas Dynamics", Prentice Hall of India, New Delhi, 2008.
4. Shapiro, AH, "Dynamics and Thermodynamics of Compressible Fluid Flow", Vols. I & II, Ronald Press, New York, 1953.

AO5014 COMBUSTION IN JET AND ROCKET ENGINES L T P C
3 0 0 3

OBJECTIVES

- To impart knowledge to the students and basic principles of combustion, types of flames and also make them familiarize the combustion process in gas turbine, ramjet, scram jet and rocket engines.

UNIT I THERMODYNAMICS OF COMBUSTION 8

Staichiometry – absolute enthalpy- enthalpy of formation- enthalpy of combustion- laws of thermochemistry- pressure and temperature effect on enthalpy of formation, adiabatic flame temperature, chemical and equillibrium products of combustion.

UNIT II PHYSICS AND CHEMISTRY OF COMBUSTION 9

Fundamental laws of transport phenomena, Conservations Equations, Transport in Turbulent Flow. Basic Reaction Kinetics, Elementary reactions, Chain reactions, Multistep reactions,simplification of reaction mechanism, Global kinetics.

UNIT III PREMIXED AND DIFFUSED FLAMES 12

One dimensional combustion wave, Laminar premixed flame, Burning velocity measurement methods, Effects of chemical and physical variables on Burning
velocity,Flame extinction, Ignition, Flame stabilizations, Turbulent Premixed flame.
Gaseous Jet diffusion flame, Liquid fuel combustion, Atomization, Spray Combustion, Solid fuel combustion.

UNIT IV COMBUSTION IN GAS TURBINE , RAMJET AND SCRAMJET 8

Combustion in gas turbine chambers, recirculation, combustion efficiency, flame holders, subsonic combustion in ramjet, supersonic combustion in scramjet. Subsonic and supersonic combustion controlled by decision mixing and heat convection.

UNIT V COMBUSTION IN CHEMICAL ROCKET 8

Combustion in liquid propellant rockets. Combustion of solid propellants- application of laminar flame theory to the burning of homogeneous propellants, Combustion in hybrid rockets. combustion instability in rockets.

TOTAL: 45 PERIODS

OUTCOME:

Upon completion of the course, students will learn about the thermodynamics, physics and chemistry of combustion.

REFERENCES

1. D. P. Mishra . " Fundamentals of Combustion", Prentice Hall of India, New Delhi, 2008.
2. H. S. Mukunda, "Understanding Combustion", 2nd edition, Orient Blackswan,2009.
3. Kuo K.K. "Principles of Combustion" John Wiley and Sons,2005.
4. Warren C. Strahle , "An Introduction to Combustion", Taylor & Francis, 1993.

AO5015 PROPELLER AERODYNAMICS

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UNIT I AIR SCREW THEORY 8

Introduction – Non-Dimensional Coefficients – Air screw design – development of airscrew theory. The actuator- disc theory, working states of rotor, optimum rotor, Efficiency of rotor.

UNIT II THE AXIAL MOMENTUM THEORY 10

The rankine-Froude theory- The momentum Equation – Ideal efficiency of a propeller. The general momentum theory- General equations – constant circulation- approximate solution- minimum loss of energy- constant efficiency. Propeller efficiency- Energy equation – approximate solution- efficiency- numerical results.

UNIT III THE BLADE ELEMENT THEORY 9

Primitive Blade Element Theory- Efficiency of the blade element- Blade interface- The vortex system of a propeller- induced velocity- The airfoil characteristics- Multi plane Interference- cascade of airfoils – Airfoil characteristics in a cascade.

UNIT IV THE VORTEX THEORY 9

The propeller blades- Energy and Momentum- Propeller characteristics – The application of the Vortex theory- The effect of solidity and pitch – Approximate method of solution- Effective Aspect ratio of the blades. Propellers of highest efficiency- Minimum loss of energy- Lightly loaded Propellers- Effect of profile drag- The effect of number of blades- Application of Prandtl's Formula.

UNIT V EXPERIMENTAL AND SIMULATION APPROACH OF PROPELLERS 9

Experimental Methods- Wind tunnel interference- Thrust and Torque distribution- Scale effect- Compressibility Effect. Basics of propeller simulations- Domain selection- Grid independency study- Turbulence model investigation.

TOTAL: 45 PERIODS

OUTCOME:

Upon completion of the course, students will gain knowledge on various Propeller theories and propeller simulations

REFERENCES:

1. Durand, W.F., "Applied Aerodynamics- Volume IV", Stanford University, California, 1934.
2. "Modeling Propeller Flow-Fields Using CFD" – AIAA 2008-402.
3. Kerwin, Justin, "lecture Notes on Hydrofoils and Propellers", Cambridge, 2001.
4. Seddon, J., "Basic Helicopter Aerodynamics", BSP Professional Books, Oxford London, 1990.

AO5009 AIRCRAFT GUIDANCE AND CONTROL

L	T	P	C
3	0	0	3

UNIT I INTRODUCTION 4

Introduction to Guidance and control - definition, Historical background

UNIT II AUGMENTATION SYSTEMS 7

Need for automatic flight control systems, Stability augmentation systems, control augmentation systems, Gain scheduling concepts.

UNIT III LONGITUDINAL AUTOPILOT 12

Displacement Autopilot-Pitch Orientation Control system, Acceleration Control System, Glide Slope Coupler and Automatic Flare Control and Flight path stabilization, Longitudinal control law design using back stepping algorithm.

UNIT IV LATERAL AUTOPILOT 10

Damping of the Dutch Roll, Methods of Obtaining Coordination, Yaw Orientation Control system, turn compensation, Automatic lateral Beam Guidance. Introduction to Fly-by-wire flight control systems, Lateral control law design using back stepping algorithm.

UNIT V MISSILE AND LAUNCH VEHICLE GUIDANCE 12

Operating principles and design of guidance laws, homing guidance laws- short range, Medium range and BVR missiles, Launch Vehicle- Introduction, Mission requirements, Implicit guidance schemes, Explicit guidance, Q guidance schemes

TOTAL: 45 PERIODS

OUTCOME:

Upon completion of the course, students will learn about longitudinal and lateral autopilot, guidance of missile and launch vehicles.

REFERENCES:
1. Bernad Etikin,'Dynamic of flight stability and control', John Wiley, 1972.
2. Blake Lock, J.H 'Automatic control of Aircraft and missiles ', John Wiley Sons, New York, 1990.
3. Collinson R.P.G, 'Introduction to Avionics', Chapman and Hall, India, 1996.
4. Garnel.P. & East.D.J, 'Guided Weapon control systems', Pergamon Press, Oxford, 1977.
5. Nelson R.C 'Flight stability & Automatic Control', McGraw Hill, 1989.
6. Stevens B.L & Lewis F.L, 'Aircraft control & simulation', John Wiley Sons, New York, 1992.

AO5092	AVIONICS	L T P C
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OBJECTIVES:
- To introduce the basic of avionics and its need for civil and military aircrafts
- To impart knowledge about the avionic architecture and various avionics data buses
- To gain more knowledge on various avionics subsystems

UNIT I INTRODUCTION TO AVIONICS 9

Need for avionics in civil and military aircraft and space systems – integrated avionics and weapon systems – typical avionics subsystems, design, technologies – Introduction to digital computer and memories.

UNIT II DIGITAL AVIONICS ARCHITECTURE 9

Avionics system architecture – data buses – MIL-STD-1553B – ARINC – 420, ARINC-429 – ARINC – 629.

UNIT III FLIGHT DECKS AND COCKPITS 9

Control and display technologies: CRT, LED, LCD, EL and plasma panel – Touch screen – Direct voice input (DVI) – Civil and Military Cockpits: MFDS, HUD, MFK, HOTAS.

UNIT IV INTRODUCTION TO NAVIGATION SYSTEMS 9

Radio navigation – ADF, DME, VOR, LORAN, DECCA, OMEGA, TACAN, ILS, MLS, Hyperbolic navigation systems, Ground Control Approach Systems. Dead reckoning navigation systems, Doppler navigational and inertial navigation– Inertial Navigation Systems (INS) – INS block diagram – Satellite navigation systems – Traffic Alert and Collision Avoidance System (TCAS), GPS.

UNIT V AIR DATA SYSTEMS AND AUTO PILOT 9

Air data quantities – Altitude, Air speed, Vertical speed, Mach meter, Total air temperature, Mach warning, Altitude warning – Auto pilot – Basic principles, Longitudinal and lateral auto pilot.

TOTAL: 45 PERIODS

OUTCOMES:
- To introduce the basic of avionics and its need for civil and military aircrafts
- To impart knowledge about the avionic architecture and various avionics data buses
- To gain more knowledge on various avionics subsystems

REFERENCES:
1. Albert Helfrick.D., "Principles of Avionics", Avionics Communications Inc., 2004
2. Collinson.R.P.G. "Introduction to Avionics", Chapman and Hall, 1996.
3. Middleton, D.H., Ed., "Avionics systems, Longman Scientific and Technical", Longman Group UK Ltd., England, 1989.
4. Spitzer, C.R. "Digital Avionics Systems", Prentice-Hall, Englewood Cliffs, N.J., U.S.A. 1993.
5. Spitzer. C.R. "The Avionics Hand Book", CRC Press, 2000
6. Pallet.E.H.J. "Aircraft Instruments and Integrated Systems", Longman Scientific.