ANNA UNIVERSITY, CHENNAI
NON- AUTONOMOUS COLLEGES AFFILIATED ANNA UNIVERSITY
M.E. AERONAUTICAL ENGINEERING
REGULATIONS 2021
CHOICE BASED CREDIT SYSTEM

I TO IV SEMESTERS CURRICULA & SYLLABI

1.PROGRAMME EDUCATIONALOBJECTIVES(PEOs): (3)

I.	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.	Graduates of the programme will have successful technical and managerial career in Aeronautical Engineering industries and the allied management.
III.	Graduates of the programme will have innovative ideas and potential to contribute for the development and current needs of the Aviation industries.

2.PROGRAMMEOUTCOMES(POs):

PO#	PROGRAMME OUTCOMES
1	An ability to independently carry out research/investigation and development work to solve practical problems
2	An ability to write and present a substantial technical report/document
3	Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program
4	Post Graduate will be trained towards developing and understanding the importance of design and development of Airplanes from system integration point of view.
5	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..
6	An understanding of professional and ethical responsibility and also capable of doing doctoral studies in multidisciplinary areas.

Note: Program may add up to three additional Pos.

4. PEO/POMapping:

PEO	PO					
	1	2	3	4	5	6
I.	2		3		2	2
II.		2		3	2	3
III.	2	3	2	2	3	3
IV.						
V.						

Every programme objectives must be mapped with 1,2,3,-, scale against the correlation PO’s

MAPPING–PG-M.E. AERONAUTICAL ENGINEERING

		COURSE NAME	PO1	PO2	PO3	PO4	PO5	PO6
YEAR I	SEMESTER I	Advanced Mathematical Methods						
		Aerospace Propulsion	2.8	2	1.8	2	1.4	1.8
		Aircraft Structural Mechanics	0	0	3	2	2.4	1
		Flight Vehicle Aerodynamics	0	0	3	1	2	1
		Research Methodology and IPR						
		Professional Elective - I						
		Audit Course – I*						
		Low Speed and High Speed Aerodynamics Laboratory	3	1	2	0	3	1
		Jet Propulsion Laboratory	3	2	2	0	2	1
	SEMESTER II	Advanced Flight Dynamics	0	0	2	2.2	1.2	1
		CFD for Aerospace Applications	0.8	0	2.6	0	1.4	1
		Finite Element Analysis	1.4	0	2.8	0	2.6	1
		Analysis of Composite Structures	0.8	0	2	0	2.2	1
		Professional Elective-II						
		Professional Elective-III						
		Audit Course – II*						
		Structures Laboratory	3	0.8	2.4	0	0	1
		Computation Laboratory	3	0.8	2.4	0	0	1
		Mini Project with Seminar						
YEAR II	SEMESTER III							
		Professional Elective-IV						
		Professional Elective-V						
		Open Elective						
		Project Work I	3	3	3	3	3	3
	SEMESTER IV	Project Work II	3	3	3	3	3	3

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CHOICE BASED CREDIT SYSTEM
I TO IV SEMESTERS CURRICULA AND SYLLABUS

I SEMESTER

SL. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.	MA4153	Advanced Mathematical Methods	FC	4	0	0	4	4
2.	AO4101	Aerospace Propulsion	PCC	3	0	0	3	3
3.	AO4102	Aircraft Structural Mechanics	PCC	3	1	0	4	4
4.	AO4103	Flight Vehicle Aerodynamics	PCC	4	0	0	4	4
5.	RM4151	Research Methodology and IPR	RMC	2	0	0	2	2
6.		Professional Elective - I	PEC	3	0	0	3	3
7.		Audit Course – I*	AC	2	0	0	2	0
PRACTICAL								
8.	AO4111	Low Speed and High Speed Aerodynamics Laboratory	PCC	0	0	4	4	2
9.	AO4112	Jet Propulsion Laboratory	PCC	0	0	4	4	2
			TOTAL	**21**	**1**	**8**	**30**	**24**

* Audit Course is optional.

II SEMESTER

SL. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.	AO4201	Advanced Flight Dynamics	PCC	3	0	0	3	3
2.	AO4202	CFD for Aerospace Applications	PCC	3	0	0	3	3
3.	AO4251	Analysis of Composite Structures	PCC	3	0	0	3	3
4.	AO4252	Finite Element Analysis	PCC	3	0	0	3	3
5.		Professional Elective-II	PEC	3	0	0	3	3
6.		Professional Elective-III	PEC	3	0	0	3	3
7.		Audit Course – II*	AC	2	0	0	2	0
PRACTICAL								
8.	AO4211	Structures Laboratory	PCC	0	0	4	4	2
9.	AO4212	Mini Project with Seminar	EEC	0	0	4	4	2
10.	AO4213	Computational Laboratory	PCC	0	0	4	4	2
			TOTAL	**20**	**0**	**12**	**32**	**24**

* Audit Course is optional.

III SEMESTER

SL. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.		Professional Elective-IV	PEC	3	0	0	3	3
2.		Professional Elective-V	PEC	3	0	0	3	3
3.		Open Elective	OEC	3	0	0	3	3
PRACTICAL								
4.	AO4311	Project Work I	EEC	0	0	12	12	6
			TOTAL	**9**	**0**	**12**	**21**	**15**

IV SEMESTER

SL. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
PRACTICAL								
1.	AO4411	Project Work II	EEC	0	0	24	24	12
			TOTAL	**0**	**0**	**24**	**24**	**12**

TOTAL CREDITS TO BE EARNED FOR THE AWARD OF THE DEGREE: 75

FOUNDATION COURSES (FC)

S. NO	COURSE CODE	COURSE TITLE	PERIODS PER WEEK			CREDITS	SEMESTER
			Lecture	Tutorial	Practical		
1.	MA4153	Advanced Mathematical Methods	4	0	0	4	1

PROGRAM CORE COURSES (PCC)

S. NO	COURSE CODE	COURSE TITLE	PERIODS PER			CREDIT S	SEMESTER
			ecture	utorial	Practical		
1.	AO4101	Aerospace Propulsion	3	0	0	3	1
2.	AO4102	Aircraft Structural Mechanics	3	1	0	4	1
3.	AO4103	Flight Vehicle Aerodynamics	4	0	0	4	1
4.	AO4111	Low Speed and High Speed Aerodynamics Laboratory	0	0	4	2	1
5.	AO4112	Jet Propulsion Laboratory	0	0	4	2	1
6.	AO4201	Advanced Flight Dynamics	3	0	0	3	2
7.	AO4202	CFD for Aerospace Applications	3	0	0	3	2
8.	AO4251	Analysis of Composite Structures	3	0	0	3	2
9.	AO4252	Finite Element Analysis	3	0	0	3	2
10.	AO4211	Structures Laboratory	0	0	4	2	2
11.	AO4261	Computation Laboratory	0	0	4	2	2

RESEARCH METHODOLOGY AND IPR COURSE (RMC)

S. NO.	COURSE CODE	COURSE TITLE	PERIODS PER WEEK			CREDITS	SEMESTER
			Lecture	Tutorial	Practical		
1.	RM4151	Research Methodology and IPR	2	0	0	2	1

PROFESSIONAL ELECTIVE COURSES (PEC)

SEMESTER I , ELECTIVE – I

SL. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
1.	AO4077	Theory of Vibrations	PEC	3	0	0	3	3
2.	AO4001	Rocketry and Space Mechanics	PEC	3	0	0	3	3
3.	AS4072	Computational Heat Transfer	PEC	3	0	0	3	3
4.	AO4002	Theory of Elasticity	PEC	3	0	0	3	3
5.	AO4003	Experimental Aerodynamics	PEC	3	0	0	3	3
6.	AO4004	Control Engineering	PEC	3	0	0	3	3

SEMESTER II, ELECTIVE – II

SL. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODSPE RWEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
1.	AO4005	Structural Dynamics	PEC	3	0	0	3	3
2.	AS4251	Hypersonic Aerodynamics	PEC	3	0	0	3	3
3.	AO4006	Advanced Propulsion Systems	PEC	3	0	0	3	3
4.	AS4071	Aerospace Materials	PEC	3	0	0	3	3
5.	AO4007	Airworthiness and Air Regulations	PEC	3	0	0	3	3
6.	AO4008	Experimental Methods of Stress Analysis	PEC	3	0	0	3	3

SEMESTER II, ELECTIVE – III

SL. NO.	COURSE CODE	COURSETITLE	CATE GORY	PERIODSPE RWEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
1.	AO4009	Aeroelasticity	PEC	3	0	0	3	3
2.	AO4076	Theory of Boundary Layers	PEC	3	0	0	3	3
3.	AO4010	Combustion in Jet and Rocket Engines	PEC	3	0	0	3	3
4.	AO4011	Gas Dynamics	PEC	3	0	0	3	3
5.	AO4072	Fatigue and Fracture Mechanics	PEC	3	0	0	3	3

SEMESTER III , ELECTIVE – IV

SL. NO.	COURSE CODE	COURSETITLE	CATE GORY	PERIODSPE RWEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
1.	AO4078	Vibration Isolation and Control	PEC	3	0	0	3	3
2.	AO4074	Non-Destructive Evaluation	PEC	3	0	0	3	3
3.	AO4012	Component Design of Aircraft Engines	PEC	3	0	0	3	3
4.	AO4013	Aircraft Systems Engineering	PEC	3	0	0	3	3
5.	AO4014	Aircraft Design	PEC	3	0	0	3	3
6.	AO4015	Composite Product Processing Methods	PEC	3	0	0	3	3

SEMESTER III, ELECTIVE – V

SL. NO.	COURSE CODE	COURSETITLE	CATE GORY	PERIODSPE RWEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
1.	AO4016	Helicopter Aerodynamics	PEC	3	0	0	3	3
2.	AO4073	High Speed Jet Flows	PEC	3	0	0	3	3
3.	AO4075	Smart Materials and Structural Health Monitoring	PEC	3	0	0	3	3
4.	AO4071	Artificial Intelligence and Machine Learning	PEC	3	0	0	3	3
5.	AO4017	Aircraft Guidance and Control	PEC	3	0	0	3	3

AUDIT COURSES (AC)
Registration for any of these courses is optional to students

SL. NO	COURSE CODE	COURSE TITLE	PERIODS PER WEEK			CREDITS
			L	T	P	
1.	AX4091	English for Research Paper Writing	2	0	0	0
2.	AX4092	Disaster Management	2	0	0	0
3.	AX4093	Constitution of India	2	0	0	0
4.	AX4094	நற்றமிழ் இலக்கியம்	2	0	0	0

EMPLOYABILITY ENHANCEMENT COURSES (EEC)

SL. NO.	COURSE CODE	COURSETITLE	PERIODSPERWEEK			CREDITS	SEMESTER
			L	T	P		
1	AO4212	Mini Project with Seminar	0	0	4	2	2
2	AO4311	Project Work I	0	0	12	6	3
3	AO4411	Project Work II	0	0	24	12	4

Summary

	Name of the Programme					
	Subject Area	**Credits per Semester**				**Total Credits**
		I	**II**	**III**	**IV**	
1.	FC	4				4
2.	PCC	15	16			31
3.	PEC	3	6	6		15
4.	RMC	2				2
5.	OEC			3		3
6.	EEC		2	6	12	20
7.	Non Credit/Audit Courses					
	Total Credit	**24**	**24**	**15**	**12**	**75**

MA4153 ADVANCED MATHEMATICAL METHODS

L	T	P	C
4	0	0	4

COURSE OBJECTIVES:

- To attain the knowledge of solving Partial Differential Equations using Laplace transform.
- To apply Fourier Transform to solve boundary value problems.
- To achieve maxima and minima of a functional.
- To acquire knowledge on using conformal mapping to fluid flow and heat flow problems.
- To understand the tensor analysis as a tool to solve problems arising in engineering disciplines.

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

COURSE 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", 6th Edition, Jones and Bartlett Publishers, 2012.
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", 3rd Edition, Prentice Hall of India Pvt. Ltd., New Delhi, 2010.
8. Spiegel, M.R., "Theory and Problems of Complex Variables and its Applications", Schaum's Outline Series, McGraw Hill Book Co., 2009.
9. Ramaniah. G. "Tensor Analysis", S. Viswanathan Pvt. Ltd., 1990.

AO4101	AEROSPACE PROPULSION	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES:

This course will enable the students

1. To gain knowledge on fundamental principles of aircraft and rocket propulsion.
2. To describe various types of propulsion system with their merits and challenges.
3. To gain adequate knowledge on propellers and its characteristics.
4. To be familiar with the working concept of inlets, nozzles and combustion chamber with their applications in a propulsion system.
5. To gain sufficient information about compressors and turbines. Students also will get an exposure on electric propulsion methods

UNIT I ELEMENTS OF AIRCRAFT PROPULSION 9

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 piston engines and Gas turbine engines – Characteristics of piston engine, turboprop, turbofan and turbojet engines, Ram jet, Scram jet – Methods of Thrust augmentation.

UNIT II PROPELLER THEORY 9

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 9

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 9

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 9

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: 45 PERIODS

COURSE OUTCOMES:

Upon completion of this course, students will

CO1: Get exposure with the different types of propulsive devices used for jet and rocket propulsion.

CO2: Have knowledge on propeller theory and its performance parameters.

CO3: Be able to distinguish different types of inlets and their performance trends in subsonic and supersonic flows.

CO4: Be able to describe the process of combustion and the parameters that affect combustion in jet engines.

CO5: Be able to acquire knowledge on the basic concepts of various types of electric propulsion systems.

REFERENCES:

1. Cohen, H, Saravanamuttoo, HIH., Rogers, GFC, Paul Straznicky and Andrew Nix , "Gas Turbine Theory", Pearson Education Canada; 7th edition, 2017.
2. Gill,WP, Smith,HJ & Ziurys,JE, "Fundamentals of Internal Combustion Engines as applied to Reciprocating, Gas turbine & Jet Propulsion Power Plants", Oxford & IBH Publishing Co., 1980.
3. Hill, PG. & Peterson, CR. "Mechanics & Thermodynamics of Propulsion" Pearson education, 2nd edition, 2014.
4. Oates, GC,"Aerothermodynamics of Aircraft Engine Components", AIAA Education Series, 2007.
5. Sutton,GP, "Rocket Propulsion Elements", John Wiley & Sons Inc., New York, 9th Edition, 2017.
6. J Seddon & E L Goldsmith. " Intake Aerodynamics", AIAA education series. 1999.

CO	PO1	PO2	PO3	PO4	PO5	PO6
	1	2	3	4	5	6
CO1	3	2	2	2	1	2
CO2	3	2	2	2	1	2
CO3	3	2	2	2	2	2
CO4	3	2	2	2	2	2
CO5	2	2	1	2	1	1
	2.8	2	1.8	2	1.4	1.8

AO4102 **AIRCRAFT STRUCTURAL MECHANICS**

L	T	P	C
3	1	0	4

COURSE OBJECTIVES:

This course will enable the students

1. To gain important technical aspects on the theory of bending of structures.
2. To learn the key aspects of shear flow in open and closed sections.
3. To study the stability problems in structures with various modes of loading.
4. To analyse aircraft structural components under various forms of loading.
5. To have basic idea about the importance of flight envelope.

UNIT I BENDING OF BEAMS 9+3

Elementary theory of pure bending – Stresses in beams of symmetrical and unsymmetrical sections – Box beams – Generalized theory of bending – Methods of bending stress determination – Principal axes method – Neutral axis method – 'k' method – Deflection of unsymmetrical beams – Stresses in Composite Beams – Idealization of cross-section – Wing spar sizing

UNIT II SHEAR FLOW IN THIN-WALLED SECTION 9+3

General stress, strain and displacement relationships for open section thin-walled beams – Concept of shear flow – Shear flow in thin walled open sections – Determinations of the shear centre – Symmetrical and unsymmetrical cross-sections – Shear flow due to bending in open sections – Torsion of thin-walled open section members & determination of stresses – Design of thin-walled members

UNIT III SHEAR FLOW IN CLOSED SECTIONS 9+3

Shear flow in thin-walled closed sections – Symmetrical and unsymmetrical sections – Flexural shear flow in two flange, three flange and multi-flange box beams – Determinations of the shear centre – Bredt-Batho theory – Torsional shear flow in multi-cell tubes – Shear flow due to combined bending and torsion – Stress analysis of aircraft components – Tapered wing spar – Introduction to shear lag

UNIT IV STABILITY PROBLEMS 9+3

Stability problems of thin walled structures – Buckling of sheets under compression, shear, and combined loads – Plate buckling coefficient – Inelastic buckling of plates – Sheet-stiffener panels – Effective width – Failure stress in plates and stiffened panels – Crippling stress estimation – Local Buckling – Wagner beam theory – Experimental determination of critical load for a flat plate – Principles of stiffener/web construction

UNIT V ANALYSIS OF AIRCRAFT STRUCTURAL COMPONENTS 9+3

Aircraft Loads – Symmetric manoeuvre loads – Load factor determination – Inertia loads – Aerodynamic loads & Schrenk's curve – The flight envelope – Shear force, bending moment and torque distribution along the span of the wing and fuselage – Structural parts of wing and fuselage and their functions – Analysis of rings and frames –– Introduction to aeroelasticity and shells.

TOTAL: 60 PERIODS

COURSE OUTCOMES:

At the end of this course, students will be able to

CO1: Apply the concept of normal stress variation in unsymmetrical sections subject to bending moments.

CO2: Find the shear flow variation in thin walled open sections with skin effective and ineffective in bending.

CO3: Evaluate the shear flow variation in single cell and multi-cell tubes subjected to shear and torque loads.

CO4: Analyse the behaviour of buckling of simply supported plates and also to know the effective width of sheet stringers combination.

CO5: Analyse and design structural members subject to compression.

REFERENCES:

1. Bruce. K. Donaldson, "Analysis of Aircraft Structures: An Introduction", Cambridge University Press, 2nd edition, 2012.
2. Bruhn. EF, " Analysis and Design of Flight Vehicle Structures", Tristate Offset Co., 1980.
3. Megson, TMG, "Aircraft Structures for Engineering Students", Elsevier, Aerospace Engineering, Series, 7th Edition, 2021.
4. Peery, DJ. And Azar, JJ, "Aircraft Structures", 2nd Edition, McGraw-Hill, New York, 1993.
5. Rivello, R.M, "Theory and Analysis of Flight structures", McGraw-Hill, N.Y., 1993.
6. Sun. CT, "Mechanics of Aircraft Structures", Wiley publishers, 2nd edition, 2006.

CO	PO1	PO2	PO3	PO4	PO5	PO6
	1	**2**	**3**	**4**	**5**	**6**
CO1			3	2	2	1
CO2			3	2	3	1
CO3			3	2	3	1
CO4			3	2	2	1
CO5			3	2	2	1
	0	0	3	2	2.4	1

AO4103	**FLIGHT VEHICLE AERODYNAMICS**	**L**	**T**	**P**	**C**
		4	**0**	**0**	**4**

COURSE OBJECTIVES:

This course will enable the students

1. To gain insights into the basics of fluid flow, its model and tool to solve the fluid flow problems.
2. To be familiar with the conservation laws of fluid dynamics, and how to apply them to practical fluid flows.
3. To gain knowledge on elementary flows to combine and form realistic flows with suitable assumptions.
4. To analyse incompressible flow over three-dimensional bodies like wing and so on.
5. To gain knowledge on the basic concepts of viscous flows, boundary layers to practical flows.

UNIT I INTRODUCTION TO AERODYNAMICS 12

Aerodynamic force and moments, lift and Drag coefficients, 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 12

Conformal Transformation, Karman ,Trefftz profiles, Kutta condition, Kelvin's Circulation Theorem and the Starting Vortex, Thin aerofoil Theory and its applications. Vortex line, Horse shoe vortex, Biot– Savart law, lifting line theory, effect of aspect ratio.

UNIT III COMPRESSIBLE FLOW THEORY 13

Compressibility, Isentropic flow through nozzles, Normal shocks, Oblique and Expansion waves, Moving shock waves, Rayleigh and Fanno Flow, Potential equation for compressible flow, Small perturbation theory, Prandtl- Glauert Rule, Linearized supersonic flow, Method of characteristics.

UNIT IV AIRFOILS, WINGS AND AIRPLANE CONFIGURATION IN HIGH SPEED FLOWS 11

Critical Mach number, Drag divergence Mach number, Shock stall, super critical airfoils, transonic area rule, Swept wings (ASW and FSW), Supersonic airfoils, Shock-Expansion Theory, Wave drag, Delta wings.

UNIT V VISCOUS FLOW THEORY 12

Basics of viscous flow theory, Boundary Layer,Flow separation, Displacement, momentum and Energy Thickness, Laminar and Turbulent boundary layers ,Boundary layer over flat plate, Blasius Solution, Estimation of skin friction drag in laminar and turbulent flow, The Reference Temperature Method.

TOTAL: 60 PERIODS

COURSE OUTCOMES:

Upon completion of this course, students will

- **CO1:** Comprehend the behaviour of airflow over bodies with particular emphasis on airfoil sections in the incompressible flow regime.
- **CO2:** Be able to solve inviscid, incompressible and irrotational flows.
- **CO3:** Be able to apply the conservation equations for fluid flows.
- **CO4:** Be provided with the knowledge on thermodynamic state of the gas behind normal shock waves, oblique shock waves and expansion waves.
- **CO5:** Be provided with adequate knowledge on the basic concepts of laminar and turbulent boundary layers.

REFERENCES:

1. J.D. Anderson, Fundamentals of Aerodynamics, McGraw-Hill Education, 6th edition, 2017.
2. Rathakrishnan.E., Gas Dynamics, Prentice Hall of India, 7th edition, 2020.
3. Shapiro, AH, "Dynamics & Thermodynamics of Compressible Fluid Flow", Ronald Press, 1982.
4. Houghton, EL and Caruthers, NB,"Aerodynamics for Engineering Students", Butterworth-Heinemann series, 7th edition 2017.
5. Zucrow, M.J, and Anderson, J.D, "Elements of gas dynamics" McGraw-Hill Book Co., New York, 1989.
6. Rae, WH and Pope, A, "Low speed Wind Tunnel Testing", John Wiley Publications, 3rd edition, 1999.

CO	PO1	PO2	PO3	PO4	PO5	PO6
	1	**2**	**3**	**4**	**5**	**6**
CO1			3	1	3	1
CO2			3	1	2	1
CO3			3	1	2	1
CO4			3	1	1	1
CO5			3	1	2	1
	0	0	3	1	2	1

RM4151 RESEARCH METHODOLOGY AND IPR **L T P C**
2 0 0 2

UNIT I RESEARCH DESIGN 6

Overview of research process and design, Use of Secondary and exploratory data to answer the research question, Qualitative research, Observation studies, Experiments and Surveys.

UNIT II DATA COLLECTION AND SOURCES 6

Measurements, Measurement Scales, Questionnaires and Instruments, Sampling and methods. Data - Preparing, Exploring, examining and displaying.

UNIT III DATA ANALYSIS AND REPORTING 6

Overview of Multivariate analysis, Hypotheses testing and Measures of Association.
Presenting Insights and findings using written reports and oral presentation.

UNIT IV INTELLECTUAL PROPERTY RIGHTS 6

Intellectual Property – The concept of IPR, Evolution and development of concept of IPR, IPR development process, Trade secrets, utility Models, IPR & Bio diversity, Role of WIPO and WTO in IPR establishments, Right of Property, Common rules of IPR practices, Types and Features of IPR Agreement, Trademark, Functions of UNESCO in IPR maintenance.

UNIT V PATENTS 6

Patents – objectives and benefits of patent, Concept, features of patent, Inventive step, Specification, Types of patent application, process E-filling, Examination of patent, Grant of patent, Revocation, Equitable Assignments, Licences, Licensing of related patents, patent agents, Registration of patent agents.

TOTAL : 30 PERIODS

REFERENCES

1. Cooper Donald R, Schindler Pamela S and Sharma JK, "Business Research Methods", Tata McGraw Hill Education, 11e (2012).
2. Catherine J. Holland, "Intellectual property: Patents, Trademarks, Copyrights, Trade Secrets", Entrepreneur Press, 2007.
3. David Hunt, Long Nguyen, Matthew Rodgers, "Patent searching: tools & techniques", Wiley, 2007.
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AO4111	LOW SPEED AND HIGH SPEED AERODYNAMICS LABORATORY	L	T	P	C
		0	0	4	2

COURSE OBJECTIVES:

This laboratory course will enable the students

1. To gain knowledge on the principles of subsonic and supersonic wind tunnel and their operation.
2. To acquire practical knowledge on various aerodynamic principles related to inviscid incompressible fluids.
3. To calculate various aerodynamic characteristics of various objects.
4. To characterize laminar and turbulent flows.
5. To get practical exposure on flow visualization techniques pertaining to subsonic flows.

LIST OF EXPERIMENTS:

1. Calibration of subsonic wind tunnel.
2. Pressure distribution over a smooth cylinder.
3. Pressure distribution over a rough cylinder.
4. Pressure distribution over a symmetric aerofoil section.
5. Pressure distribution over a cambered aerofoil section.
6. Pressure distribution over a wing of cambered aerofoil section.
7. Study on Force and moment measurements by using strain gauge.
8. Wake measurements behind a bluff body.
9. Velocity boundary layer measurements over a flat plate.
10. Force and moment measurements on aircraft model by using strain gauge.
11. Force and Moment measurements using wind tunnel balance.
12. Calibration of supersonic wind tunnel.
13. Subsonic flow visualization studies.

Any 10 experiments may be conducted.

TOTAL: 60 PERIODS

COURSE OUTCOMES:

At the end of this course, students will be

CO1: Able to operate and calibrate subsonic and supersonic wind tunnel.
CO2: Able to analyse the pressure distribution over the streamlined and bluff bodies.
CO3: Able to carry out measurement of force and moments on aircraft models.
CO4: Capable of measuring boundary layer thickness over various models.
CO5: Able to carry out flow visualization at subsonic speeds.

LABORATORY EQUIPMENTS REQUIRED

1. Subsonic wind tunnel
2. Rough and smooth cylinder
3. Symmetrical and Cambered aerofoil
4. Wind tunnel balance
5. Schlieren system
6. Pressure Transducers
7. Supersonic wind tunnel
8. Blower
9. Testing models like flat plate, bluff body

CO	PO1	PO2	PO3	PO4	PO5	PO6
	1	2	3	4	5	6
CO1	3	1	2		3	1
CO2	3	1	2		3	1
CO3	3	1	2		3	1
CO4	3	1	2		3	1
CO5	3	1	2		3	1
	3	1	2	0	3	1

AO4112 JET PROPULSION LABORATORY

L	T	P	C
0	0	4	2

COURSE OBJECTIVES:

This course will enable the students

1. To gain knowledge on wall pressure distribution on subsonic and supersonic inlets and nozzles.
2. To perform testing on compressor blades.
3. To interpret the experimental data using software.
4. To get practical exposure on flow visualization techniques pertaining to supersonic jets.
5. To gain basic knowledge on cold flow studies.

LIST OF EXPERIMENTS:

1. Wall pressure measurements of a subsonic diffuser.
2. Cascade testing of compressor blades.
3. Pressure distribution on a cavity model.
4. Wall pressure measurements on non-circular combustor.
5. Wall pressure measurements on converging nozzle.
6. Wall pressure measurements on convergent-divergent nozzle.
7. Total pressure measurements along the jet axis of a circular subsonic jet.
8. Total pressure measurements along the jet axis of a circular supersonic jet.
9. Total pressure measurements in the radial direction of the subsonic jet.
10. Total pressure measurements in the radial direction of the supersonic jet.
11. Cold flow studies of a wake region behind flame holders.
12. Wall pressure measurements on supersonic inlets.
13. Flow visualization on supersonic jets.
14. Prediction of flow angles using angle probe.

Any 10 experiments may be conducted.

TOTAL: 60 PERIODS

COURSE OUTCOMES:

At the end of the course, students will be

CO1: Able to perform wall pressure distribution on subsonic and supersonic nozzles.

CO2: Able to acquire knowledge on fundamental concepts of low speed and high speed jets and experimental techniques pertains to measurements.

CO3: Provided with adequate knowledge on pressure distribution on cavity models.

CO4: Able to perform wake survey methods.

CO5: Able to carry out flow visualization on supersonic jets.

LABORATORY EQUIPMENTS REQUIRED

1. Subsonic wind tunnel
2. High speed jet facility
3. Blower
4. Pressure scanner
5. Schlieren system
6. Nozzle and cavity models

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
	1	**2**	**3**	**4**	**5**	**6**
CO1	3	2	2		2	1
CO2	3	2	2		2	1
CO3	3	2	2		2	1
CO4	3	2	2		2	1
CO5	3	2	2		2	1
	3	2	2	0	2	1

AO4201	**ADVANCED FLIGHT DYNAMICS**	**L**	**T**	**P**	**C**
		3	**0**	**0**	**3**

COURSE OBJECTIVES:

This course will enable students

1. To gainin depth knowledge on aircraft performance in level, climbing, gliding flight modes.
2. To get familiarize the equations of motion in accelerated flight modes.
3. To impart knowledge on the basic aspects of stability and control of an airplane about three axis.
4. To provide adequate knowledge on various parameters that decide the stability level of an airplane.
5. To be familiar with the aspects of control in longitudinal, lateral and directional modes.

UNIT I STEADY FLIGHT PERFORMANCE 9

Overview of Aerodynamics and ISA – Straight and level flight: thrust and power required/available, differences of propeller-driven and jet-powered airplanes, maximum speed, effects of altitude – Climb and Descent performance: climb angle and rate of climb, descent angle and rate of descent – Range, endurance of propeller driven and jet powered airplanes.

UNIT II MANEUVER PERFORMANCE 9

Level turn – maximum producible load factor – fastest and tightest turn – Vertical maneuver: pull-up and pull-out, pull-down – gust V-n diagram –Take off and landing performance.

UNIT III STATIC LONGITUDINAL STABILITY AND CONTROL 9

Static equilibrium and stability – Pitch stability of conventional and canard aircraft – control fixed neutral point and static margin – effect of fuselage and running propellers on pitch stability – control surface hinge moment – control free neutral point – limit on forward CG travel –maneuver stability: Pull – up & level turn – control force and trim tabs – control force for maneuver– measurement of neutral point and maneuver point by flight tests.

UNIT IV STATIC LATERAL, DIRECTIONAL STABILITY AND CONTROL 9

Yaw and side slip, effect of wing sweep, wing dihedral and vertical tail on directional stability – rudder fixed and rudder free – yaw control – rudder sizing – pedal force - dihedral effect: contribution of various components- roll control.

UNIT V AIRCRAFT DYNAMICS 9

Rigid body equations of motion - Axes systems and their significance – Euler angles – linearization of longitudinal equations – force and moment derivatives – short period and phugoid approximations – pure pitching motion – linearization of equations for lateral – directional motion – roll, spiral and dutch roll approximations- Pure rolling- Pure yawing – Inertia coupling.

L : 45, TOTAL: 45 PERIODS

COURSE OUTCOMES:

At the end of this course, students will

CO1: Be able to assess the performance of aircraft in steady and maneuver flights.
CO2: Have thorough knowledge in order to perform preliminary design computations to meet static stability and trim requirements of aircrafts.
CO3: Be able to determine the fixed neutral point and the stick fixed static margin.
CO4: Be able to describe the effect of change in CG on the aircraft stability.
CO5: Apply the small disturbance equations of motion, and identify longitudinal and lateral sets of equations, construct state space models for longitudinal and lateral aircraft dynamics.

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
	1	**2**	**3**	**4**	**5**	**6**
CO1			2	2		1
CO2			2	2	2	1
CO3			2	2	3	1
CO4			2	2	1	1
CO5			2	3		1
	0	0	2	2.2	1.2	1

REFERENCES:

1. Anderson,JD, "Aircraft Performance & Design", First edition, Mc Graw Hill India, 2010.
2. McCormick, BW, "Aerodynamics, Aeronautics, & Flight Mechanics", 2nd edition, John Wiley & Sons, 1995.
3. Michael V. Cook, "Flight Dynamics Principles", Second edition, Elsevier, 2007.
4. Nelson, RC,"Flight Stability & Automatic Control", Second edition, McGraw-Hill, 2017.
5. Perkins CD &Hage, RE,"Airplane performance, stability and control", Wiley India Pvt Ltd, 2011.
6. Brain else stephsnos, Frank loie aircraft simulation and control, AIAA

AO4202 CFD FOR AEROSPACEAPPLICATIONS **L T P C**

3 0 0 3

COURSE OBJECTIVES:

This course will make the students

1. To get familiarize with the procedure to obtain numerical solution to fluid dynamic problems.
2. To gain knowledge on the important aspects of grid generation for practical problems.
3. To get exposure on time dependant and panel methods.
4. To learn the techniques pertaining to transonic small perturbation force.
5. To make use of commercial CFD software for aerospace applications.

UNIT I NUMERICAL SOLUTIONS OF SOME FLUID DYNAMICAL PROBLEMS 9

Basic fluid dynamics equations, Equations in general orthogonal coordinate system, Body fitted coordinate systems, mathematical properties of fluid dynamic equations and classification of partial differential equations - 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-Panel methods.

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 aerofoil and CD nozzle. Unstructured grids, Cartesian grids, hybrid grids, grid around typical 2D and 3D geometries – Overlapping grids – Grids around multi bodies.

UNIT III 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 IV FINITE VOLUME METHOD 9

Introduction to Finite volume Method - Different Flux evaluation schemes, central, upwind and hybrid schemes - Staggered grid approach - Pressure-Velocity coupling - SIMPLE, SIMPLER algorithms- pressure correction equation (both incompressible and compressible forms) - Application of Finite Volume Method -artificial diffusion.

UNIT V CFD FOR INDUSTRIAL APPLICATIONS 9

Various levels of approximation of flow equations, turbulence modelling for viscous flows, verification and validation of CFD code, application of CFD tools to 2D and 3D configurations. CFD for kinetic heating analysis – Coupling of CFD code with heat conduction code, Unsteady flows – Grid movement method, Oscillating geometries, Computational aeroelasticity – Coupling of CFD with structural model – Aeroelasticity of airfoil geometry, Introduction to commercial CFD software for aerospace applications, High performance computing for CFD applications – Parallelization of codes –domain decomposition.

TOTAL: 60 PERIODS

COURSE OUTCOMES:
At the end of this course, students will be able
CO1: To arrive at the numerical solutions to boundary layer equations.
CO2: To perform numerical grid generation and have knowledge about the mapping techniques.
CO3: To familiarise himself/herself with high performance computing for CFD applications.
CO4: To implement the explicit time dependent methods and their factorization schemes.
CO5: To do the stability analysis and linearization of the implicit methods.

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
	1	**2**	**3**	**4**	**5**	**6**
CO1			2		1	1
CO2			3		2	1
CO3	2		3		1	1
CO4			3		2	1
CO5	2		2		1	1
	0.8	0	2.6	0	1.4	1

REFERENCES:

1. Bose. TK, “Numerical Fluid Dynamics”,Narosa Publishing House, 2001.
2. Chung. TJ, “Computational Fluid Dynamics”, Cambridge University Press, 2010.
3. Hirsch,AA, “Introduction to Computational Fluid Dynamics”, McGraw-Hill, 1989.
4. John D. Anderson, “Computational Fluid Dynamics”, McGraw Hill Education, 2017.
5. SedatBiringen&Chuen-Yen Chow, “Introduction to Computational Fluid Dynamics by Example”, Wiley publishers, 2nd edition, 2011.
6. Wirz, HJ &Smeldern, JJ, “Numerical Methods in Fluid Dynamics”, McGraw-Hill & Co., 1978.

AO4251 **ANALYSIS OF COMPOSITE STRUCTURES**

L	T	P	C
3	**0**	**0**	**3**

COURSE OBJECTIVES:
This course will make students
1. To impart knowledge on the macro mechanics of composite materials.
2. To determine stresses and strains in composites and also imparts an idea about the manufacturing methods of composite materials.
3. To get an idea on failure theories of composites.
4. To provide the basic knowledge on the properties of fibre and matrix materials used in commercial composites as well as some common manufacturing techniques.
5. To gain knowledge on the basic concepts of acoustic emission technique.

UNIT I FIBERS, MATRICES, AND FABRICATION METHODS 9
Production & Properties of Glass, Carbon and Aramid Fibers – Thermosetting and Thermoplastic Polymers – Polymer Properties of Importance to the Composite, Summary of Fabrication Processes – Scope of Composite Materials for Various Aerospace Application.

UNIT II MICROMECHANICS OF A UNIDIRECTIONAL COMPOSITE 9

Volume and Weight Fractions in a Composite Specimen – Longitudinal Behaviour of Unidirectional Composites – Load Sharing – Failure Mechanism and Strength – Factors Influencing Longitudinal Strength and Stiffness – Transverse Stiffness· and Strength – Prediction of Elastic Properties Using Micromechanics –Typical Unidirectional Fiber Composite Properties – Minimum and Critical Fiber Volume Fractions.

UNIT III MACROMECHANICS APPROACH 9

Stress Analysis of an Orthotropic Lamina-Hooke's Law-Stiffness and Compliance Matrices - Specially Orthotropic Material-Transversely Isotropic Material & Specially Orthotropic Material under Plane Stress-Determination of E_x, E_y, G_{xy}-Stress & Strain Transformations- Transformation of Stiffness and Compliance Matrices-Strengths of an Orthotropic Lamina Using Different Failure Theories.

UNIT IV ANALYSIS OF LAMINATED COMPOSITES 10

Laminate Strains - Variation of Stresses in a Laminate - Resultant Forces and Moments - Synthesis of Stiffness Matrix - Laminate Description System - Construction and Properties of Special Laminates - Symmetric Laminates – Balanced Laminate - Cross-Ply, and Angle-Ply Laminates - Quasi-isotropic Laminates - Determination of Laminae Stresses and Strains – Determination of Hygrothermal Stresses - Analysis of Laminates after Initial Failure.

UNIT V ANALYSIS OF LAMINATED PLATES AND BEAMS 8

Governing Equations For Laminated Composite Plates -- Governing Equations for Laminated Beams -Application of Theory – Bending, Buckling and Vibration of Laminated Beams and Plates repair-Analysis of sandwich construction-AE technique.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

Upon completion of this course, students will be able

CO1: To calculate the elastic and strength properties of unidirectional laminates using micromechanics theory.

CO2: To analyze a composite laminate using the different failure theories.

CO3: To select the most appropriate manufacturing process for fabricating composite components.

CO4: To demonstrate understanding of the different materials (fibres, resins, cores) used in composites.

CO5: To gain knowledge on non-destructive inspection (NDI) and structural health monitoring of composites.

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
	1	**2**	**3**	**4**	**5**	**6**
CO1	2		2		3	1
CO2	2		2		3	1
CO3			2		2	1
CO4			2		2	1
CO5			2		1	1
	0.8	0	2	0	2.2	1

REFERENCES:
1. Agarwal, BD and Broutman, LJ, “Analysis and Performance of Fibre Composites”, John Wiley & Sons, 3rd edition, 2006.
2. Allen Baker, “Composite Materials for Aircraft Structures”, AIAA Series, 2nd Edition, 2004.
3. Autar K Kaw, “Mechanics of Composite Materials”, CRC Press, 2nd edition, 2005.
4. Calcote, LR, “The Analysis of laminated Composite Structures”, Von – Nostrand Reinhold Company, New York, 1998.
5. Isaac M. Daniel &OriIshai ,“Mechanics of Composite Materials”, OUP USA publishers, 2nd edition, 2005.
6. Lubing, “Handbook on Advanced Plastics and Fibre Glass”, Von Nostran Reinhold Co., New York, 1989.

AO4252 FINITE ELEMENT ANALYSIS L T P C

3 0 0 3

COURSE OBJECTIVES:

This course will enable the students

1. To learn the concepts of finite element methods and the various solution schemes available.
2. To impart knowledge to solve plane stress and plane strain problems.
3. To solve heat transfer and fluid mechanics problems using Finite element methods.
4. To formulate mass and stiffness element matrices for vibration problems.
5. To be familiar in obtaining solutions to fluid flow problems.

UNIT I INTRODUCTION 9

Review of various approximate methods – Rayleigh-Ritz, Galerkin and Finite Difference Methods – Problem Formulation – Application to Structural Elements & Practical Problems – Derivation ofStiffness and Flexibility Matrices – Spring Systems – Role of Energy Principles – Basic Concepts of Finite Element Method – Interpolation, Nodes, Degrees of Freedom – Solution Schemes.

UNIT II DISCRETE ELEMENTS 9

Finite Element Structural Analysis Involving 1-D Bar and Beam Elements – Tapered Bar – Temperature Effects – Static Loading – Formulation of the Load Vector for 1-D Elements – Methods of Stiffness Matrix Formulation – Interpolation & Shape Functions – Boundary Conditions – Determination of Displacements & Reactions – Constitutive Relations – Determination of Nodal Loads & Stresses.

UNIT III CONTINUUM ELEMENTS 9

Plane Stress & Plane strain Loading – CST Element – LST Element – Element Characteristics – Problem Formulation & Solution Using Finite Elements – Axisymmetric Bodies & Axisymmetric Loading – Consistent and Lumped Load Vectors – Use of Local, Area and Volume Co-ordinates – Isoparametric Formulation – Shape Functions – Role of Numerical Integration – Load Consideration – Complete FE Solution.

UNIT IV VIBRATION & BUCKLING 9

Formulation of the Mass and Stiffness Element Matrices for Vibration Problems – Bar and Beam Elements – Derivation of the Governing Equation – Natural Frequencies and Modes – Damping Considerations –Harmonic Response – Response Calculation Using Numerical Integration – Buckling of Columns – Problem Formulation – Solution – Determination of Buckling Loads and Modes.

UNIT V HEAT TRANSFER & FLUID MECHANICS PROBLEMS 9

One Dimensional Heat Transfer Analysis – Formulation of the Governing Equations in Finite Element Form – Equivalent Load Vector – Solution & Temperature Distribution – Finite Element Formulation & Solution for Sample Problems Involving Fluid Mechanics .

TOTAL: 45 PERIODS

COURSE OUTCOMES:

At the end of this course, students will have

CO1: An ability to frame governing equations involving different type of finite elements.

CO2: Knowledge onthe general finite element methodology for a variety of practical problems.

CO3: An ability to solve simple 1-D and 2-D problems using the finite element method.

CO4: Knowledge on how to apply numerical integration techniques effectively in finite elements solutions.

CO5: An ability to frame and solve heat transfer and fluid mechanics problems using the FE method.

REFERENCES:

1. Bathe, KJ &Wilson,EL, Numerical Methods in Finite Elements Analysis, Prentice Hall of India Ltd., 1983.
2. Dhanaraj, R &K.PrabhakaranNair,K, Finite Element Method, Oxford university press, India, 2015.
3. Krishnamurthy,CS, Finite Elements Analysis, Tata McGraw – Hill, 1987.
4. Rao,SS Finite Element Method in Engineering, Butterworth, Heinemann Publishing, 3rd Edition, 1998.
5. Robert D. Cook, David S. Malkus, Michael E. Plesha and Robert J. Witt, Concepts and Applications of Finite Element Analysis, John Wiley & Sons, 4th Edition, 2002.
6. Segerlind,LJ, Applied Finite Element Analysis, , John Wiley and Sons Inc., New York, 2nd Edition,1984.
7. Tirupathi R. Chandrupatla& Ashok D. Belegundu, Introduction to Finite Elements in Engineering, Prentice Hall, 2002.

CO	PO1	PO2	PO3	PO4	PO5	PO6
	1	2	3	4	5	6
CO1	1		3		2	1
CO2	1		2		2	1
CO3	2		3		3	1
CO4	1		3		3	1
CO5	2		3		3	1
	1.4	0	2.8	0	2.6	1

AO4211 **STRUCTURES LABORATORY** **L T P C**

0 0 4 2

COURSE OBJECTIVES:

This laboratory course enables the students

1. To get practical knowledge on calibration of photoelastic materials.
2. To gain practical exposures on calculating shear centre locations for closed and open sections.
3. To provide with the basic knowledge of fabricating a composite laminate.
4. To have basic knowledge on unsymmetrical bending of beams.
5. To design and conduct different types of practical tests involving various aircraft structural components.

LIST OF EXPERIMENTS

1. .Calibration of photo elastic materials
2. Experimental modal analysis
3. Forced vibration testing
4. Fabrication and static testing of composite laminates
5. Non-destructive evaluation of defects in composite laminates using acoustic emission
6. Non-destructive evaluation of defects in composite laminates using ultrasonics.
7. Whirling of composite shafts
8. Design, Fabrication and testing of a 3-D printed specimen.
9. Unsymmetrical bending of beams
10. Determination of influence coefficients and flexibility matrix
11. Shear centre location for open & closed thin-walled sections
12. Buckling of columns with different end conditions
13. Experimental verification of the Wagner beam theory

NOTE: Any 10experiments will be conducted out of 15.

TOTAL: 60 PERIODS

COURSE OUTCOMES:

At the end of the course, studentswill be able

CO1: To conduct tests and interpret data involving strain gauges.
CO2: To get exposure on experimental methods in photoelasticity.
CO3: To design an experimental evaluation technique for a given application.
CO4: To comprehend non-destructive testing methods.
CO5: To fabricate of composite laminates and characterizes it.

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
	1	**2**	**3**	**4**	**5**	**6**
CO1	3	2	3			1
CO2	3		2			1
CO3	3	2	2			1
CO4	3		2			1
CO5	3		3			1
	3	0.8	2.4	0	0	1

LABORATORY EQUIPMENTS REQUIRED

1. Electrical resistance strain gauges installation kit.
2. Circuit board with resistors, wires, clips, etc, and strain gauges.
3. Column testing set-up (with provision for different end conditions)
4. Unsymmetrical beam bending set-up.
5. Dial gauges & travelling microscope.
6. Experimental setup for location of shear centre (open & closed sections)
7. Whirling of shafts demonstration unit.
8. Photo-elastic models.
9. Equipment for the fabrication of composite laminates.
10. Testing instruments and equipment for acoustic emission testing.
11. Testing instruments and equipment for ultrasonics testing.
12. Diffuser transmission type polariscope with accessories
13. Experimental setup for vibration of beams& vibration measuring instruments.
14. Universal Testing Machine.
15. 3-D printing machine.
16. Wagner beam & accessories.

AO4213	COMPUTATIONAL LABORATORY (Consists of FEM & CFD experiments)	L T P C 0 0 4 2

COURSE OBJECTIVES:

1. This course is intended to make students familiar with different types of structural analysis using finite element software
2. This course helps students to correctly interpret the results of simulation.
3. To equip with the knowledge base essential for application of computational fluid dynamics to engineering flow problems.
4. To provide the essential numerical background for solving the partial differential equationsgoverning the fluid flow.
5. To develop students' skills of using a commercial software package

EXPERIMENTS IN FEM

LIST OF EXPERIMENTS:

1. Grid generation methods and geometry clean up techniques.
2. Static analysis of a uniform bar subject to different loads -1-D element
3. Thermal stresses in a uniform and tapered member – 1-D element
4. Static analysis of trusses / frames under different loads
5. Stress analysis & deformation of a beam using 1-D element & 2-D – incorporation of
7. discrete, distributed, and user-defined loads
6. Static analysis of a beam with additional spring support
7. Stress concentration in an infinite plate with a small hole
8. Bending of a plate with different support conditions
9. Stability analysis of a plate under in-plane loads
10. Buckling of solid and thin-walled columns under different end conditions

11. Free vibration analysis of a bar / beam
12. Forced response of a bar / beam under harmonic excitation
13. Heat transfer analysis using 1-D & 2-D elements – conduction and convection
14. Modelling and analysis of a laminated plate
15. Impact analysis of a laminated plate.

Minimum of 6 Experiments to be performed by using FEM Software tools

EXPERIMENTS IN CFD

LIST OF EXPERIMENTS:

1. Numerical simulation of 1-D diffusion and conduction in fluid flows
2. Numerical simulation of 1-D convection-diffusion problems
3. Numerical simulation of 2-D unsteady state heat conduction problem
4. Numerical simulation of 2-D diffusion and 1-D convection combined problems
5. Structured grid generation over airfoil section3-D numerical simulation of flow through CD nozzles
6. 3-D numerical simulation of flow development of a subsonic and supersonic jets
7. Numerical simulation of boundary layer development
8. Numerical simulation of subsonic combustion in a ramjet combustor
9. Numerical simulation of transonic flow over airfoils

Minimum of 6 Experiments to be performed by using CFD Software tools

TOTAL: 60 PERIODS

COURSE OUTCOMES:

At the end of this course, students will be able

CO1: To get solution of aerodynamic flows.
CO2: To perform stability analysis of structural components.
CO3: To define and setup flow problem properly within CFD context, performing solid modelling using CAD package and producing grids via meshing tool.
CO4: To comprehend both flow physics and mathematical properties of governing Navier-Stokes equations and define proper boundary conditions for solution.
CO5: To use CFD software to model relevant engineering flow problems.

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
	1	**2**	**3**	**4**	**5**	**6**
CO1	3		2			1
CO2	3		2			1
CO3	3	2	3			1
CO4	3	2	3			1
CO5	3		2			1
	3	0.8	2.4	0	0	1

LABORATORY EQUIPMENTS REQUIREMENTS

1. Desktop computers
2. MS visual C++
3. CFD software

AO4212 **MINI PROJECT WITH SEMINAR** **L T P C**
0 0 4 2

Seminar is to be given by the student after the completion of a mini project chosen by the student. Topics for the mini projects can be from the aeronautical engineering and allied fields. The mini project can be based on either numerical or analytical solution or design or fully experimental; or a combination of these tasks.

AO4311 **PROJECT WORK I** **L T P C**
0 0 12 6

COURSE OBJECTIVES:

1. A research project work must be carried out completed with reference to the published literatures or from the creative ideas of the students themselves in consultation with their project supervisor.
2. To improve the student research and development activities.

EVALUATION:
Project work evaluation is based on Regulations of Credit system of Affiliated Institutions - Post graduate programmes of Anna University.

TOTAL : 90 PERIODS

COURSE OUTCOME:
The students' would apply the knowledge gained from theoretical and practical courses in solving problems, so as to give confidence to the students to be creative, well planned, organized, coordinated project outcome of the aimed work.

AO4411 **PROJECT WORK II** **L T P C**
0 0 24 12

COURSE OBJECTIVES:

1. The objective of the research project work is to produce factual results of their applied research idea in the field of Aeronautical Engineering, developed from Project Work- I or may be a new concept with innovation.
2. The progress of the project is evaluated based on a minimum of three reviews.
3. The review committee may be constituted by the Head of the Department.
4. A project report is required at the end of the semester. The project work is evaluated jointly by external and internal examiners constituted by the Head of the Department based on oral presentation and the project report.
5. To improve the student research and development activities.

EVALUATION:

Project work evaluation is based on Regulations of Credit system of Affiliated Institutions - Post graduate programmes of Anna University.

TOTAL : 180 PERIODS

COURSE OUTCOME:
The students' would apply the knowledge gained from theoretical and practical courses in solving problems, so as to give confidence to the students to be creative, well planned, organized, coordinated project outcome of the aimed work.

AO4077	THEORY OF VIBRATIONS	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES:
This course will enables students

1. To get insight into the basic aspects of vibration theory.
2. This course presents the principles of dynamics and energy methods pertaining to structures.
3. This course provides a platform for better understanding of the approximate methods for aerospace structures.
4. To get insight into the dynamic responses of the large systems.
5. To get insight into the basic aspects of aero-elasticity.

UNIT I SINGLE DEGREE OF FREEDOM SYSTEMS 9
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 9
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 9
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 9
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 9
Aeroelastic problems – Collar's triangle of forces – Wing divergence – Aileron control reversal – Flutter.

TOTAL: 45 PERIODS

REFERENCES
1. Timoshenko, S. "Vibration Problems in Engineering", John Wiley & Sons, Inc., 2018.
2. Meirovitch, L. "Elements of Vibration Analysis", New Delhi, McGraw-Hill Education, 2014.
3. Thomson W.T, Marie Dillon Dahleh, "Theory of Vibrations with Applications", Harlow, Essex Pearson 2014
4. F.S. Tse., I.F. Morse and R.T. Hinkle, "Mechanical Vibrations", Prentice-Hall of India, 1985.
5. Rao.J.S. and Gupta.K. "Theory and Practice of Mechanical Vibrations", New Delhi, New Age International, 1999.
6. Fung, Y.C., "An Introduction to the Theory of Aeroelasticity", Dover Publications., Mineola, N.Y., 2008.

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	-	2	3	3	-
CO2	3	-	2	3	3	-
CO3	3	-	2	3	3	-
CO4	3	-	2	3	3	-
CO5	3	-	2	3	3	-

AO4001 ROCKETRY AND SPACE MECHANICS **L T P C**
3 0 0 3

COURSE OBJECTIVES:
1. This course presents the fundamental aspects of rocket motion along with detailed estimation of rocket trajectories.
2. This course also imparts knowledge on optimization of multistage rockets.
3. This course provides the basics of space mechanics required for an aeronautical student
4. This course helps students to provide with the basics of orbit transfer of satellites.
5. This course will help students to gain knowledge on various control methods of rockets.

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 – orbit transfer and examples –Hohmann orbits – calculation of orbit parameters– Determination of satellite rectangular coordinates from orbital elements- satellite epiphermis.

UNIT III ROCKET MOTION 9
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 – rocket stability – rocket dispersion – launching problems.

UNIT V STAGING AND CONTROL OF ROCKET VEHICLES 9

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

COURSE OUTCOMES:

Upon completion of this course, students will be able

CO1: To knowledge on the fundamental laws of orbital mechanics with particular emphasis on interplanetary trajectories.

CO2: To calculate orbital parameters and perform conceptual trajectory designs for geocentric or interplanetary missions.

CO3: To familiarize themselves with trajectory calculations for planar motion of rockets.

CO4: To determine forces and moments acting on airframe of a missile.

CO5: To acquire knowledge on the need for staging and stage separation dynamics of rocket vehicles.

REFERENCES:

1. Cornelisse,JW, "Rocket Propulsion and Space Dynamics", J.W. Freeman & Co., Ltd., London, 1982.
2. Parker,ER,"Materials for Missiles and Spacecraft", McGraw-Hill Book Co., Inc., 1982.
3. Suresh. B N & Sivan. K, "Integrated Design for Space Transportation System", Springer India, 2016.
4. Sutton,GP, Biblarz,O, "Rocket Propulsion Elements", John Wiley & Sons Inc., New York, 9th Edition, 2017.
5. Van de Kamp, "Elements of Astromechanics", Pitman Publishing Co., Ltd., London, 1980.

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
	1	**2**	**3**	**4**	**5**	**6**
CO1	3		2			1
CO2	3		2	2	3	1
CO3	3		3	2	3	1
CO4	3		2			1
CO5	3		3	2	2	1
	3	0	2.4	1.2	1.6	1

AS4072 COMPUTATIONAL HEAT TRANSFER

L	T	P	C
3	0	0	3

COURSE OBJECTIVES:

This course will enable students

1. To get insights into the basic aspects of various discretization methods.
2. To provide basic ideas on the types of PDE's and its boundary conditions to arrive at its solution.
3. To impart knowledge on solving conductive, transient conductive and convective problems using computational methods.
4. To solve radiative heat transfer problems using computational methods.
5. To provide a platform for students in developing numerical codes for solving heat transfer problems.

UNIT I INTRODUCTION 9

Finite Difference Method-Introduction-Taylor's series expansion-Discretization Methods Forward, backward and central differencing scheme for first 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

COURSE OUTCOMES:

Upon completion of this course, Students will

CO1: Have an Idea about discretization methodologies for solving heat transfer problems.
CO2: Be able to solve 2-D conduction and convection problems.
CO3: Have an ability to develop solutions for transient heat conduction in simple geometries.
CO4: Be capable of arriving at numerical solutions for conduction and radiation heat transfer problems.
CO5: Have knowledge on developing numerical codes for practical engineering heat transfer problems.

REFERENCES:

1. Chung,TJ, “Computational Fluid Dynamics”, Cambridge University Press, 2002.
2. Holman,JP, “Heat Transfer”, McGraw-Hill Book Co, Inc., McGraw-Hill College; 10th edition, 2017.
3. John D. Anderson, “Computational Fluid Dynamics”, McGraw Hill Education, 2017.
4. John H. Lienhard, “A Heat Transfer”, Text Book, Dover Publications, 5th edition, 2020.
5. Richard H. Pletcher, John C. Tannehill & Dale Anderson, “Computational Fluid Mechanics and Heat Transfer”, 4th edition, CRC Press, 2021
6. Sachdeva,SC, “Fundamentals of Engineering Heat & Mass Transfer”, New age publisher, 4th edition Internationals, 2017.

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	-	2	3	3	-
CO2	3	-	2	3	3	-
CO3	3	-	2	3	3	-
CO4	3	-	2	3	3	-
CO5	3	-	2	3	3	-

AO4002 THEORY OF ELASTICITY L T P C
3 0 0 3

COURSE OBJECTIVES:

This course will enable students

1. To learn the basic concepts and equations of elasticity.
2. To provide with the concepts of plain stress and strain related problems.
3. To gain knowledge on equilibrium and stress-strain equations of polar coordinates.
4. Will be exposed to axisymmetric problems.
5. To get insight into the basic concepts of plates and shells.

UNIT I BASIC EQUATIONS OF ELASTICITY 9

Definition & sign convention for stress and strain – Hooke’s law – Relation between elastic constants – Equilibrium and compatibility equations – Analysis of stress, strain and deformation – Stress and strain transformations equations – Cauchy’s formula – Principal stress and principal strains in 2D & 3D – Octahedral stresses and its significance – Boundary conditions.

UNIT II APPLIED CONCEPTS 9

Plane stress and plane strain problems – Airy stress function – Biharmonic equation – Compatibility equation in terms of stress – Solution of bar and beam problems using the elasticity approach – Torsion of bars – Determination of stresses, strain and displacements – Warping of cross-sections – Prandtl’s stress function approach – St. Venant’s method.

UNIT III POLAR COORDINATES 9

Strain-displacement relations in polar coordinates – Equilibrium and stress-strain equations in polar coordinates – Infinite plate with a small central hole – Stress concentration – Bending of a curved beam (Winkler-Bach theory) – Deflection of a thick curved bar – Stresses in straight and curved beams due to thermal loading – Thermal stresses in cylinders and spheres – Stress concentration in bending.

UNIT IV AXISYMMETRIC PROBLEMS 9

Equilibrium and stress-strain equations in cylindrical coordinates – Lame's problem – Thick-walled cylinders subject to internal and external pressure – Application of failure theories – Stresses in composite tubes – Shrink fitting – Stresses due to gravitation – Analysis of a rotating disc of uniform thickness – Discs of variable thickness – Rotating shafts and cylinders.

UNIT V PLATES AND SHELLS 9

Classical plate theory – Assumptions, governing equations and boundary conditions – Navier's method of solution – Levy's method of solution – Rectangular and circular plates – Solution techniques – Analysis of a shell – Membrane Theory – Deformation and stresses due to applied loads.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

Upon completion of this course, students will

CO1: Have knowledge of basic elasticity relationships and equations.

CO2: Know how to carry out stress analysis in 2-D and 3-D.

CO3: Get exposure on the formulation of constitutive and governing equations for basic problems in cartesian and cylindrical coordinates.

CO4: Be able to analyse and solve practical problems in cartesian and cylindrical coordinates.

CO5: Be able to determine the stress, strain and displacement field for common axisymmetrical members.

REFERENCES:

1. Harry Kraus, "Thin Elastic Shells", John Wiley and Sons, 1987.
2. Flugge, W, "Stresses in Shells", Springer – Verlag, 1990.
3. Timoshenko, S.P. and Gere, J.M, "Theory of Elastic Stability", McGraw Hill Book Co. 2010.
4. Timoshenko, S.P. Winowsky. S., and Kreger, "Theory of Plates and Shells", McGraw Hill Book Co., 2nd edition, 2015.
5. Varadan, TK andBhaskar,K, "Analysis of plates-Theory and problems", Narosha Publishing Co., 2001.

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
	1	**2**	**3**	**4**	**5**	**6**
CO1	1		2			1
CO2	3		2		2	1
CO3	1		2			1
CO4	3		2		3	1
CO5	2		2		2	1
	2	0	2	0	1.4	1

AO4003 EXPERIMENTAL AERODYNAMICS L T P C
3 0 0 3

COURSE OBJECTIVES:

1. This course will enable the students to learn basics of wind tunnel operation and its associated measurements.
2. To present the concepts of different flow visualization methods.
3. This course also imparts knowledge on flow measurement variables
4. This course enables students to be familiar with data acquisition methods pertaining to experiments in aerodynamics.
5. This course will help students to do uncertainty analysis for their experiments.

UNIT I LOW SPEED TUNNEL 9

Objective of experimental studies, Types of wind tunnels, Low speed tunnel, Energy ratio, Power losses in a wind tunnel – Calibration of subsonic wind tunnels – Speed Setting – Flow Direction – Three-Hole and Five-Hole Yaw Probes – Turbulence – Wind tunnel balance – Water tunnel.

UNIT II HIGH SPEED TUNNEL 9

Transonic wind tunnel – Transonic Test Section – Supersonic wind tunnels – Losses in Supersonic Tunnels – Supersonic Wind Tunnel Diffusers– Effects of Second Throat – Runtime calculation –Calculating Air Flow Rates –Calibration of Supersonic Wind Tunnels – Hypersonic wind tunnel and Calibration –Ludwieg Tube – Shock tube and shock tunnels – Gun tunnel – Plasma arc tunnels – Measurement of shock speed.

UNIT III FLOW VISUALIZATION TECHNIQUES 9

Visualization techniques – Smoke tunnel –-Dye Injection –Bubble Techniques –Surface Flow Visualization techniques – oil – Tufts –China Clay – Ultraviolet Fluorescence Photography – Interferometer – Fringe-Displacement method – Shadowgraph –Schlieren system – Background Oriented Schlieren (BOS) system – Laser sheet flow visualization.

UNIT IV MEASUREMENTS OF PROPERTIES 9

Pressure measurement techniques-Pitot, Static, and Pitot-Static Tubes-Pitot-Static tube characteristics – Pressure Sensitive Paints - Pressure transducers – Velocity measurements – Hot-wire anemometry-Constant current and Constant temperature Hot-Wire anemometer – Hot-film anemometry - Laser Doppler Velocimetry (LDV) – Particle Image Velocimetry (PIV)- Temperature measurements – Measurement of heat flux – Foil type heat flux gauge –Transient analysis of foil gauge– Thin film sensors – Slug type heat flux sensor.

UNIT V DATA ACQUISITION SYSTEMS AND UNCERTAINTY ANALYSIS 9

Data acquisition and processing – Signal conditioning – Statistical analysis of experimental data – Regression analysis – Estimation of measurement errors – Uncertainty calculation – Uses of uncertainty analysis.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

Upon completion of this course, students will

CO1: Have knowledge on measurement of flow properties in wind tunnels and their associated instrumentation.

CO2: Be able to demonstrate and conduct experiments related to subsonic and supersonic flows.

CO3: Gain idea on flow visualization of subsonic and supersonic flows.

CO4: Be familiar with calibration of transducers and other devices used for flow measurement.

CO5: Be able to estimate errors and to perform uncertainty analysis of the experimental data.

REFERENCES:

1. Allan Pope and Kenneth L Goin, “High Speed Wind Tunnel Testing”, Krieger Publishing Company, 1978.
2. Jewel B. Barlow, Willian. H.Rae and Allan Pope,“Low-Speed Wind Tunnel Testing”, Wiley-Interscience, 3rd edition, 1999.
3. Rathakrishnan, E, “Instrumentation, Measurements, and Experiments in Fluids”, CRC Press –Taylor & Francis, 2020.
4. Robert B Northrop, “Introduction to Instrumentation and Measurements”, Second Edition, CRC Press, Taylor & Francis, 2017.

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
	1	**2**	**3**	**4**	**5**	**6**
CO1	1	2	2		1	1
CO2	3	3	2		3	1
CO3	2	2	2		2	1
CO4	3	3	2		3	1
CO5	3	2	2		3	1
	2.4	2.4	2	0	2.4	1

AO4004	**CONTROL ENGINEERING**	**L**	**T**	**P**	**C**
		3	**0**	**0**	**3**

COURSE OBJECTIVES:

1. To introduce the mathematical modeling of systems, open loop and closed loop systems and analyses in time domain and frequency domain.
2. To impart the knowledge on the concept of stability and various methods to analyze stability in both time and frequency domain.
3. To introduce sampled data control system.

UNIT I INTRODUCTION 9

Historical review, Simple pneumatic, hydraulic and thermal systems, Series and parallel system, Analogies, mechanical and electrical components, Development of flight control systems.

UNIT II OPEN AND CLOSED LOOP SYSTEMS 9

Feedback control systems – Control system components - Block diagram representation of control systems, Reduction of block diagrams, Signal flow graphs, Output to input ratios.

UNIT III CHARACTERISTIC EQUATION AND FUNCTIONS 9

Laplace transformation, Response of systems to different inputs viz., Step impulse, pulse, parabolic and sinusoidal inputs, Time response of first and second order systems, steady state errors and error constants of unity feedback circuit.

UNIT IV CONCEPT OF STABILITY 9

Necessary and sufficient conditions, Routh-Hurwitz criteria of stability, Root locus and Bode techniques, Concept and construction, frequency response.

UNIT V SAMPLED DATA SYSTEMS 9

Z-Transforms Introduction to digital control system, Digital Controllers and Digital PID controllers

TOTAL: 45 PERIODS

COURSE OUTCOMES:

1. Ability to apply mathematical knowledge to model the systems and analyse the frequency domain
2. Ability to check the stability of the both time and frequency domain
3. Ability to solve simple pneumatic, hydraulic and thermal systems, Mechanical and electrical component analogies based problems.
4. Ability to solve the Block diagram representation of control systems, Reduction of block diagrams, Signal flow graph and problems based on it.
5. Ability to understand the digital control system, Digital Controllers and Digital PID Controllers.

REFERENCES:

1. Azzo, J.J.D. and C.H. Houpis, “Feed back control system analysis and synthesis”, McGraw-Hill international 3rs Edition, 1998.
2. OGATO, Modern Control Engineering, Pearson, New Delhi, 2016.

CO	PO1	PO2	PO3	PO4	PO5	PO6
	1	2	3	4	5	6
CO1	1		2	1	1	1
CO2	1		2	1	1	1
CO3	1		2	1	1	1
CO4	1		2	1	1	1
CO5	1		2	1	1	1
	1	0	2	1	1	1

AO4005 STRUCTURAL DYNAMICS

L	T	P	C
3	0	0	3

COURSE OBJECTIVES:

1. This course imparts knowledge on the force deflection properties of structures and natural modes of vibration.
2. This course also presents the principles of dynamics and energy methods pertaining to structures.
3. This course will make students to realise the importance of natural modes of vibration.
4. This course will provide in-depth knowledge on natural vibrations of beams and plates.
5. This course also provides a platform for better understanding of the approximate methods for aerospace structures.

UNIT I FORCE DEFLECTION PROPERTIES OF SYSTEMS 9

Constraints and Generalized coordinates – Virtual work and generalized forces – Force – Deflection influence functions – stiffness and flexibility methods.

UNIT II PRINCIPLES OF DYNAMICS 9

Free and forced vibrations of systems with finite degrees of freedom – Response to periodic excitation – Impulse Response Function – Convolution Integral

UNIT III NATURAL MODES OF VIBRATION 9

Equations of motion for Multi degree of freedom Systems – Solution of Eigen value problems – Normal coordinates and orthogonality Conditions. Modal Analysis

UNIT IV ENERGY METHODS 9

Rayleigh's principle – Rayleigh – Ritz method – Coupled natural modes – Effect of rotary inertia and shear on lateral vibrations of beams – Natural vibrations of beams and plates.

UNIT V APPROXIMATE METHODS 9

Approximate methods of evaluating the Eigen frequencies and eigen vectors by reduced, subspace, Lanczos, Power, Matrix condensation and QR methods.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

At the end of this course, students will

CO1: Be able to solve the equation of motion of a linear system and use this solution to analyse the vibrational behaviour of the system.

CO2: Be capable to relate the results of a modal analysis relate to the vibration of a structure.

CO3: Acquire knowledge on equation of motion of a lumped MDOF mass-spring-damper system.

CO4: Have knowledge on vibration characteristics ofcontinuous system such as strings, bar, shafts andbeams.

CO5: Be able to assess the fundamental frequency of MDOF systems using approximate methods.

CO	PO1	PO2	PO3	PO4	PO5	PO6
	1	**2**	**3**	**4**	**5**	**6**
CO1	2		2	2	2	1
CO2			2	2		1
CO3			3	2	2	1
CO4			3	2		1
CO5			2	2		1

REFERENCES:

1. Hurty,WC and Rubinstein,MF,"Dynamics of Structures", Prentice Hall of India Pvt.Ltd.,New Delhi 1987.
2. Ramamurthi,V, "Mechanical Vibration Practice and Noise Control", Narosa Publishing House Pvt. Ltd, 2008.
3. Timoshenko,SP and Young,DH,"Vibration Problems in Engineering", John Willey & Sons Inc., 1984.
4. Tse.FS, Morse, IE and Hinkle,HT,"Mechanical Vibrations: Theory and Applications", Prentice Hall of India Pvt. Ltd, New Delhi, 2004.
5. Vierck,RK,"Vibration Analysis", 2ndEdition, Thomas Y. Crowell/ Harper & Row Publishers, New York, U.S.A. 1989.

AS4251 HYPERSONIC AERODYNAMICS

L T P C
3 0 0 3

COURSE OBJECTIVES:

This course will enables students

1. To realise the importance of studying the peculiar hypersonic speed flow characteristics pertaining to flight vehicles.
2. To provide knowledge on various surface inclination methods for hypersonic inviscid flows.
3. To arrive at the approximate solution methods for hypersonic flows.
4. To impart knowledge on hypersonic viscous interactions.
5. To impart knowledge on the effect on aerodynamic heating on hypersonic vehicles.

UNIT I INTRODUCTION TO HYPERSONIC AERODYNAMICS9

Peculiarities of Hypersonic flows - Thin shock layers – entropy layers – low density and high density flows – hypersonic flight similarity parameters – shock wave and expansion wave relations of inviscid hypersonic flows – velocity vs altitude map for hypersonic vehicles.

UNIT II SURFACE INCLINATION METHODS FOR HYPERSONIC INVISCID FLOWS 8

Local surface inclination methods – modified Newtonian Law – Newtonian theory – tangent wedge tangent cone and shock expansion methods – Calculation of surface flow properties – practical application of surface inclination methods – hypersonic independence principle.

UNIT III APPROXIMATE METHODS FOR INVISCID HYPERSONIC FLOWS 10

Assumptions in approximate methods hypersonic small disturbance equation and theory – Maslen''s theory– blast wave theory – hypersonic equivalence principle- entropy effects - rotational method of characteristics - hypersonic shock wave shapes and correlations.

UNIT IV VISCOUS HYPERSONIC FLOW THEORY 10

Peculiarities of hypersonic boundary layers - boundary layer equations r – hypersonic boundary layer theory and non similar hypersonic boundary layers – hypersonic aerodynamic heating and entropy layers effects on aerodynamic heating – heat flux and skin friction estimation.

UNIT V VISCOUS INTERACTIONS AND TRANSITION 8

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

TOTAL: 45 PERIODS

COURSE OUTCOMES:

Upon completion of the course, students will

CO1: Be able to arrive at the solution for problems involving inviscid and viscous hypersonic flows.

CO2: Have thorough knowledge on high temperature effects in hypersonic aerodynamics.

CO3: Be able to arrive at various solution methods to overcome aerodynamic heating problem on hypersonic vehicles.

CO4: To gain ideas on the design issues associated with hypersonic vehicles.

CO5: Able to realize the importance and use of the relevant equations for viscous hypersonic flows.

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	✓	✓	✓	✓	✓	
CO2	✓	✓	✓	✓		
CO3	✓	✓	✓	✓	✓	
CO4	✓	✓	✓	✓	✓	
CO5	✓	✓	✓	✓		

REFERENCES:

1. Anderson, JD, "Hypersonic and High Temperature Gas Dynamics", AIAA Education Series, 2nd edition, 2006.
2. Anderson, JD, "Modern compressible flow: with Historical Perspective", McGraw Hill Education, 3rd edition, 2017.
3. William H. Heiser and David T. Pratt, Hypersonic Air Breathing propulsion, AIAA Education Series, 1994.
4. John T. Bertin, Hypersonic Aerothermodynamics, AIAA Education Series, 1993.

AO4006 ADVANCED PROPULSION SYSTEMS L T P C

3 0 0 3

COURSE OBJECTIVES:

1. This course will cover the basic aspects of thermodynamic cycle analysis of air-breating propulsion systems.
2. This course is intended to impart knowledge on advanced air breathing propulsion systems like air augmented rockets.
3. This course will give the knowledge on the basic aspects of scramjet propulsion system.
4. This course will provide in-depth knowledge about the nozzle performance.
5. This course also presents vast knowledge onthe operating principles of nuclear, electric and ion propulsion.

UNIT I THERMODYNAMIC CYCLE ANALYSIS OF AIR-BREATHING PROPULSION SYSTEMS 9

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 10

Fundamental considerations of hypersonic air breathing vehicles – Preliminary concepts in engine airframe integration – calculation of propulsion flow path – flow path 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 radioisotope propulsion systems.

UNIT V ELECTRIC AND ION PROPULSION 9

Basic concepts in electric propulsion – power requirements and rocket efficiency – classification of thrusters – electrostatic thrusters – plasma thruster– Fundamentals of ion propulsion – performance analysis – ion rocket engine.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

At the end of this course, students will be

CO1: Able to Analyse in detail the thermodynamics cycles of air breathing propulsion systems.

CO2: Able to gain idea on the concepts of supersonic combustion for hypersonic vehicles and its performance.

CO3: Able to demonstrate the fundamental requirements of supersonic combustors.

CO4: Capable of estimating performance parameters of nuclear and electrical rockets.

CO5: Able to acquire knowledge on the concepts of engine-body installation on hypersonic vehicles.

CO	PO1	PO2	PO3	PO4	PO5	PO6
	1	**2**	**3**	**4**	**5**	**6**
CO1	3		2	2	3	1
CO2	3		2		2	1
CO3	3		3		2	1
CO4			3		3	1
CO5	2		2		2	1

REFERENCES:

1. Cumpsty, "Jet propulsion", Cambridge University Press, 2003.
2. Fortescue and Stark, "Spacecraft Systems Engineering", Wiley, 4th edition, 2011.
3. Sutton, GP, "Rocket Propulsion Elements", John Wiley & Sons Inc., New York, 1998.
4. William H. Heiser and David T. Pratt, "Hypersonic Air breathing propulsion", AIAA Education Series, 2001.

AS4071 AEROSPACE MATERIALS L T P C
3 0 0 3

COURSE OBJECTIVES:

This course will enable students

1. To get insights into the basic aspects of material science.
2. To provide basic idea on the mechanical behaviour of materials.
3. To impart knowledge on the macro mechanics of composite materials,
4. To gain knowledge on the analysis andmanufacturing methods of composite materials.
5. To learn about the sandwich construction.

UNIT I MATERIAL SCIENCE 9

Crystallography of metals & metallic alloys – Imperfections – Dislocations in Different Crystal Systems – Effect on plasticity – Strengthening Mechanisms Due to Interaction of Dislocations with Interfaces – Other Strengthening Methods – Dislocation Generation Mechanisms

UNIT II MECHANICAL BEHAVIOUR 9

Stress-strain curve and mechanical behaviour of materials – linear elasticity and plasticity – failure of ductile and brittle materials – use of failure theories – maximum normal stress and maximum shear stress failure theories – importance of the octahedral stress failure theory – failure theories based on strain energy – cyclic loading and fatigue of materials – the S-N curve

UNIT III METALLIC ALLOYS 9

Metals and alloys used for different aerospace applications – Properties of conventional and advanced aerospace alloys – Effect of alloying elements – Summary of conventional and state-of-the-art manufacturing processes – Types of heat treatment and their effect – other processing parameters – Materials for aerospace application – Design requirements & standards

UNIT IV HIGH TEMPERATURE MATERIALS 9

Carbon-Carbon Composites and Ceramic Materials For High Temperature Aerospace Application – Manufacturing Technologies & Controlling Parameters – Mechanical and Thermal Properties of These Material Systems – Thermal Protection Material System for a Re-Entry Vehicle – Use of Superalloys – Metal Matrix Composites &Cermets – Properties and Applications – Mechanical and Thermal Fatigue

UNIT V SMART MATERIALS 9

Introduction to smart materials-shape memory effects-shape memory alloys-shape memory polymers-electro-rheological fluids-energy harvesting materials-self healing polymers.

TOTAL : 45 PERIODS

COURSE OUTCOMES:

Upon completion of this course, students will

CO1: Be able to investigate the physical and mechanical behaviour of different materials.
CO2: Have exposure on dislocation theories and their importance.
CO3: Have general knowledge of the properties of different aerospace materials
CO4: Be able to apply failure theories appropriately.
CO5: Be able to select good materials for a specific aerospace application.

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	✓		✓			
CO2	✓	✓	✓		✓	✓
CO3	✓	✓	✓		✓	✓
CO4	✓	✓	✓		✓	
CO5	✓		✓			✓

REFERENCES

1. Adrian Mouritz, "Introduction to Aerospace Materials", Woodhead Publishing, 1st edition, 2012.
2. Jones. R M, "Mechanics of Composite Materials", 2nd Edition, CRC Press, Taylor & Francis Group, 1998.
3. Prasad, N. Eswara, Wanhill, RJH, "Aerospace Materials and Material TechnologiesVolume 1: Aerospace Materials", Springer Singapore, 2017.
4. Sam Zhang &Dongliang Zhao, "Aerospace Materials Handbook", CRC Press, Taylor & Francis Group, 2012.
5. Brain culshaw, smart structures and materials, Artech house, 2000.

AO4007 AIRWORTHINESS AND AIR REGULATIONS L T P C
3 0 0 3

COURSE OBJECTIVES:

This course will make students

1. To get insight into the basic aspects of aircraft rules.
2. To gain knowledge on the basic concepts of airworthiness.
3. To learn the basic aspects on certification and publication procedures.
4. To impart knowledge on licensing and material selections.
5. To provide with the concepts of case studies and civil aviation requirements.

UNIT I INTRODUCTION TO AIRCRAFT RULES 8

Airworthiness requirements for civil and military aircraft – CAA, FAA, JAR and ICAO regulations – Defence standards – Military standards and specifications.

UNIT II BASIC CONCEPTS OF AIRWORTHINESS 9

Privileges and responsibilities of various categories of AME license and approved persons – Knowledge of mandatory documents like certificate of Registration – Certificate of Airworthiness – Conditions of issue and validity – Export certificate of Airworthiness – Knowledge of Log Book, Journey Log Book, Technical Log Book etc.

UNIT III CERTIFICATION AND PUBLICATION PROCEDURES 10

Procedure for development and test flight and Certification – Certificate of Flight release – Certificate of Maintenance – Approved Certificates – Technical Publications – Aircraft Manual – Flight Manual – Aircraft Schedules – Registration Procedure, Certification, Identification and Marking of Aircraft**.**

UNIT IV LICENSING AND MATERIAL SELECTIONS 9

Modifications – Concessions – Airworthiness directives – Service bulletins – Crew training and their licenses – approved inspection – Approved materials – Identification of approved materials – Bonded and quarantine stores**.**

UNIT V CASE STUDIES AND CIVIL AVIATION REQUIREMENTS 9

Storage of various aeronautical products like rubber goods and various fluids – Accident investigation procedures – Circumstances under which C of A is suspended – ICAO and IATA regulations – Chicago and Warsaw conventions – Familiarization of recent issues of Advisory Circulars – Civil Aviation Requirements Section 2 – Airworthiness.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

Upon completion of this course, students will be able

CO1: To realise the importance of aircraft rules.
CO2: To get exposure on the basic concepts of airworthiness.
CO3: To develop test flight and Certification.
CO4: To carry out inspections and can identify the approved materials.
CO5: To analyse the case studies and realise the importance of civil aviation requirements.

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
	1	**2**	**3**	**4**	**5**	**6**
CO1			2	3	3	1
CO2			2	3	3	1
CO3			2	3	3	1
CO4			2	3	3	1
CO5			2	3	3	1

REFERENCES:

1. Civil Airworthiness Requirements (www.dgca.nic.in), 2016.
2. Civil Aircraft Airworthiness Information and Procedures (CAP 562).
3. Civil Aviation Requirements Section 2 - Airworthiness.
4. Gran E L and Richard Levenworth, Statistical Quality Control, 7^{th} Edition McGraw Hill,1997
5. Manual of Civil Aviation/ Organisation Manual DGCA, 2017.
6. The Indian Aircraft Act and the Rules(www.dgca.nic.in),2008.

AO4008 EXPERIMENTAL METHODS OF STRESS ANALYSIS L T P C
3 0 0 3

COURSE OBJECTIVES:

1. This course introduces the basic principles and methods of experimental stress analysis.
2. This course helps to learn the principles and techniques of photoelastic measurements.
3. This course presents the principles and techniques of moire analysis.
4. This course helps to gain knowledge of the principles and a technique of strain gage measurements is presented.
5. This course also enables the students to learn basic principles of operation of electrical resistance strain gauges, interferometric techniques, and non destructive methods.

UNIT I BASIC CONCEPTS 9

Stresses, Strains and Displacements – Determination of Principal Values of Stresses and Strains in 2-D & 3-D – Maximum Shear Stress – Strain Measurement Using Mechanical Extensometers – Principles of Measurements – Basic Characteristics and Requirements of a Measuring System – Sources of error – Statistical Analysis of Experimental Data – Non-Contact Measurement.

UNIT II ELECTRICAL-RESISTANCE STRAIN GAGES 9

Strain Sensitivity in Metallic Alloys –Gage Construction –Gage Sensitivities and Gage Factor – Performance Characteristics of Foil Strain Gages – Environmental Effects –The Three-Element Rectangular Rosette –Corrections for Transverse Strain Effects – Other Types of Strain Gages – Semiconductor Strain Gages – Grid & Brittle Coating Methods of Strain Analysis.

UNIT III STRAIN-GAGE CIRCUITS & INSTRUMENTATION 9

The Potentiometer Circuit and Its Application to Strain Measurement – Variants From The Basic Potentiometer Circuit – Circuit Output – The Wheatstone Bridge Constant Current and Constant Voltage Circuits – Circuit Sensitivity – Calibrating Strain-Gage Circuits –Effects of Lead Wires and Switches – Electrical Noise Reduction – Strain Measurement in Bars, Beams and Shafts.

UNIT IV PHOTOELASTIC METHODS OF STRESS ANALYSIS 9

Introduction – Stress-Optic Law – Effects of a Stressed Model in a Plane Polariscope– Effects of a Stressed Model in a Circular Polariscope– Tardy Compensation – Two-Dimensional Photoelastic Stress Analysis – Fringe Multiplication and Fringe Sharpening – Properties of Commonly Employed Photoelastic Materials – Material Calibration – Introduction to Three-Dimensional Photoelasticity and digital photo elasticity.

UNIT V NON-DESTRUCTIVE TESTING 8

Different types of NDT Techniques – Acoustic Emission Technique – Ultrasonic – Pulse-Echo – Through Transmission – Eddy Current Testing – X-Ray Radiography – Challenges in Non-Destructive Evaluation – Non-Destructive Evaluation in Composites – Concepts of Image Processing Theory.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

Upon completion of this course, Students will have

CO1: Knowledge of different methods of strain measurement.
CO2: Knowledge on electrical resistance strain gauge.
CO3: An ability to design experiments for strain measurements.
CO4: Acquired knowledge on photo elastic methods of stress analysis.
CO5: Exposure to non-destructive testing methods.

CO	PO1	PO2	PO3	PO4	PO5	PO6
	1	**2**	**3**	**4**	**5**	**6**
CO1			2	2		1
CO2			2	2		1
CO3	2		3			1
CO4			3	2		1
CO5			2	3		1

REFERENCES:

1. Albert S. Kobayashi,“Handbook on Experimental Mechanics”, Prentice Hall Publishers, 1987.
2. James W. Dally & William F. Riley, “Experimental Stress Analysis”, McGraw-Hill College, 1991.
3. James F. Doyle & James W. Phillips, “Manual on Experimental Stress Analysis”, 5th Edition, Society for Experimental Mechanics, 1989.
4. Sharpe Jr& William N, Springer, “Handbook of Experimental Solid Mechanics”, Springer, 2008.
5. Udpa. S.S & Patrick O. Moore, “Non-destructive Testing Handbook”, Electromagnetic Testing, Third Edition: Volume 5, 2004.
6. Ramesh, IIT Madras

AO4009 AEROELASTICITY L T PC

30 0 3

COURSE OBJECTIVES:

1. This course provides the basic knowledge on aero elastic phenomena and its impact on aircraft design.
2. This course will make students to illustrate the aeroelastic phenomena using simplified aerodynamic and structural models
3. This course provides insight into both static and dynamic aeroelastic phenomena and possible prevention methods.
4. This course imparts knowledge on the flutter phenomena in detail.
5. This course provides the basic knowledge on prevention and control of aeroelastic instabilities.

UNIT I AEROELASTIC PHENOMENA 8

Stability versus response problems – introduction to aeroelasticity and aeroelastic phenomena – Examples of aeroelastic phenomena – Galloping of transmission lines – Flow induced vibrations of tall slender structures – Instability of suspension bridges – Fluid structure interaction – The aero-elastic triangle of forces – Prevention of aeroelastic instabilities

UNIT II MODELLING OF AEROELASTIC PHENOMENA 9

Influence and stiffness co-efficients – illustration of aeroelastic phenomena using simplified aerodynamic and structural models – different subsonic and supersonic aerodynamic models for aeroelastic analysis – modelling techniques – aeroelastic models in state-space format Flexure – torsional oscillations of beams – Governing differential equation of motion and its solution

UNIT III STATIC AEROELASTIC PHENOMENA 10

Simple two dimensional idealisation – Strip theory – Exact solutions for simple rectangular wings – 'Semirigid' assumption and approximate solutions – Successive approximation method – Numerical approximations using matrix equations – Divergence of 2-D airfoil and Straight Wing – Aileron efficiency & reversal – Control Effectiveness – Wing deformations of swept wings

UNIT IV FLUTTER CALCULATIONS 10

Flutter analysis – Two dimensional thin airfoils in steady incompressible flow –Quasi-steady 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 Calculation – U-g Method – P-k Method – Exact Treatment of Bending –Torsion Flutter of a Uniform Wing – Flutter Analysis by Assumed Mode Method

UNIT V PREVENTION AND CONTROL 8

Stiffness criteria – dynamic mass balancing – dimensional similarity – effect of elastic deformation on static longitudinal stability – introduction to aeroelastic control – aeroelastic aspects in the design of aircraft – Panel flutter and its control – Prevention of tail buffeting – Aeroelastic instabilities in helicopter and engine blades and prevention methods

TOTAL: 45 PERIODS

COURSE OUTCOMES:

Upon completion of this course, students will

CO1: Have knowledge of the role of aeroelasticity in aircraft design.

CO2: Interpret the use of semi-rigid body assumptions and numerical methods in airplane design.

CO3: Arrive at the solutions for steady state aeroelastic problem.

CO4: Be knowledge with the concept of flutter analysis of aircraft wings.

CO5: Have knowledge on practical examples of aeroelastic problems.

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
	1	**2**	**3**	**4**	**5**	**6**
CO1			2			1
CO2	3		2	3	2	1
CO3	3		2		2	1
CO4			2			1
CO5			2	3		1

REFERENCES:

1. Bisplinghoff.RL, Ashley,H and Halfmann,RL, "Aeroelasticity", 2nd Edition, Addison Wesley Publishing Co., Inc., 1996.
2. Blevins, RD,"Flow Induced Vibrations", Krieger Pub Co., 2001.
3. Broadbent,EG,"Elementary Theory of Aeroelasticity", Bun Hill Publications Ltd., 1986.
4. Fung,YC, "An Introduction to the Theory of Aeroelasticity", John Wiley & Sons Inc., New York, 2008.
5. Scanlan, RH and R.Rosenbaum, "Introduction to the study of Aircraft Vibration and Flutter", Macmillan Co., New York, 1981.

AO4076 THEORY OF BOUNDARY LAYERS **L T P C**

3 0 0 3

COURSE OBJECTIVES:

1. This course imparts knowledge to students on growth of boundary layer and its effect on the aerodynamic design of airframe of flight vehicles.
2. This course will introduce them the solution methods for boundary layer problems.
3. This course enables the students to understand the importance of viscosity and boundary layer in fluidflow.
4. This course also introduces the theory behind laminar and turbulent boundary layers.
5. This course will make students to learn the concepts of boundary layer transition and separation.

UNIT I THEORY OF VISCOUS FLOW 8

Fundamental equations of viscous flow, Conservation of mass, Conservation of Momentum-Navier-Stokes equations, Energy equation, Mathematical character of basic equations, Dimensional parameters in viscous flow, Non-dimensionalising the basic equations and boundary conditions, vorticity considerations, creeping flow, boundary layer flow.

UNIT II INCOMPRESSIBLE VISCOUS FLOWS AND BOUNDARY LAYER 10

Solutions of viscous flow equations, Couette flows, Hagen-Poisuelle flow, Flow between rotating concentric cylinders, Combined Couette-Poiseuille Flow between parallel plates, Creeping motion, Stokes solution for an immersed sphere, Development of boundary layer, Displacement thickness, momentum and energy thickness.

UNIT III LAMINAR BOUNDARY LAYER THEORY 10

Laminar boundary layer equations, Flat plate Integral analysis of Karman – Integral analysis of energy equation – Laminar boundary layer equations – boundary layer over a curved body-Flow separation- similarity solutions, Blasius solution for flat-plate flow, Falkner–Skan wedge flows, Boundary layer temperature profiles for constant plate temperature –Reynold's analogy, Integral equation of Boundary layer – Pohlhausen method – Thermal boundary layer calculations.

UNIT IV THEORY OF TURBULENT BOUNDARY LAYER 9

Turbulence-physical and mathematical description, Two-dimensional turbulent boundary layer equations –– Velocity profiles – The law of the wall – The law of the wake – Turbulent flow in pipes and channels – Turbulent boundary layer on a flat plate – Boundary layers with pressure gradient, Eddy Viscosity, mixing length , Turbulence modelling.

UNIT V BOUNDARY LAYER TRANSITION AND SEPARATION 8

Boundary layer control in laminar flow-Methods of Boundary layer control: Motion of the solid wall-Acceleration of the boundary layer-Suction- Injection of different gas-Prevention of transition-Cooling of the wall-Boundary layer suction-Injection of a different gas.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

Upon completion of this course, students will be able

CO1: To apply proper governing equations for various types of viscous flows in engineering applications.
CO2: To obtain solutions for various viscous flow problems in engineering.
CO3: To estimate skin friction over solid surfaces, over which laminar boundary layer persists.
CO4: To arrive at the solutions for turbulent boundary layer and the resulting drag.
CO5: To gain insights on the techniques for boundary layer control.

CO	PO1	PO2	PO3	PO4	PO5	PO6
	1	**2**	**3**	**4**	**5**	**6**
CO1			2	2	3	1
CO2			2	3	3	1
CO3			2	3	3	1
CO4			2	2	3	1
CO5			2	1	3	1

REFERENCES:

1. White, F. M., Viscous Fluid Flow, McGraw-Hill & Co., Inc., New York, 2008.
2. Schlicting, H., Boundary Layer Theory, McGraw-Hill, New York, 1979.
3. Reynolds, A, J., Turbulent Flows Engineering, John Wiley and Sons, 1980.

AO4010 COMBUSTION IN JET AND ROCKET ENGINES L T P C
3 0 0 3

COURSE OBJECTIVES:

1. This course provides the basic principles of combustion, types of flames and also familiarizes the combustion process in gas turbine, ramjet, scram jet and rocket engines.
2. This course explains the concept of thermochemistry, enthalpy, adiabatic flame temperature, combustion products and their application to combustion related problems.
3. This course presents the concept of chemical rates of reaction, collision theory and Arrhenius equation for analysing the different types of reactions.
4. This course gives an idea to compare the properties and characteristics of different type of flames and apply the same to combustion phenomenon in rocket motors and its exhaust.
5. This course also imparts knowledge to interpret the various combustion processes that take place inchemical rockets.

UNIT I THERMODYNAMICS OF COMBUSTION 8

Stoichiometry – absolute enthalpy- enthalpy of formation- enthalpy of combustion- laws of thermochemistry- pressure and temperature effect on enthalpy of formation, adiabatic flame temperature, chemical and equilibrium 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 10

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 and diffusion flame - Examples -. Differences between premixed flame and diffusion.

UNIT IV COMBUSTION IN GAS TURBINE, RAMJET AND SCRAMJET 9

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

UNIT V COMBUSTION IN CHEMICAL ROCKET 9

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

COURSE OUTCOMES:

At the end of this course, students will be able to

CO1: Apply the basic concept of thermochemistry to combustion related problems

CO2: Demonstrate the concept of chemical kinetics in combustion reactions.

CO3: Differentiate between deflagration and detonation process and interpret the concept for computation and analysis of the transition phenomenon.

CO4: Demonstrate the peculiarities of supersonic combustion.

CO5: Evaluate the combustion processes taking place in different types of chemical rockets.

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
	1	**2**	**3**	**4**	**5**	**6**
CO1			2	3	2	1
CO2			2	2	3	1
CO3	2		3	2	3	1
CO4			3	3	2	1
CO5	2		2	3	3	1

REFERENCES:

1. Kuo, KK, “Principles of Combustion”, John Wiley and Sons, 2005.
2. Mishra, DP, “Fundamentals of Combustion”, Prentice Hall of India, New Delhi, 2008.
3. Mukunda, HS, “Understanding Combustion”, 2nd edition, Orient Blackswan,2009.
4. Warren C. Strahle, “An Introduction to Combustion”, Taylor & Francis, 1993.

AO4011	**GAS DYNAMICS**	**L**	**T**	**P**	**C**
		3	**0**	**0**	**3**

COURSE OBJECTIVES:

This course will enable the students

1. To gain insights into the steady one-dimensional fluid flow, its model and tool to solve the fluid flow problems.
2. To acquire knowledge about the normal shock waves.
3. To acquire knowledge about the oblique shock and expansion waves.
4. To gain knowledge about the basic measurements involved in compressible flows.
5. To acquire basic knowledge about the rarefied and high temperature gas dynamics.

UNIT I STEADY ONE-DIMENSIONAL FLOW 10

Thermodynamics of Fluid Flow – First Law of Thermodynamics - The Second Law of Thermodynamics - Thermal and Calorical Properties – Perfect Gas - Wave Propagation – Velocity of Sound - Subsonic and Supersonic Flows – Fundamental Equations - Discharge from a Reservoir – Stream tube Area-Velocity Relation - De Laval Nozzle – Supersonic Flow Generation – Diffusers - Dynamic Head Measurement in Compressible Flow - Pressure Coefficient.

UNIT II NORMAL SHOCK WAVES 10

Introduction – Equations of Motion for a Normal Shock Wave - The Normal Shock Relations for a Perfect Gas - Change of Stagnation or Total Pressure across the Shock- Hugoniot Equation - The Propagating Shock Wave - Reflected Shock Wave - Centered Expansion Wave - Shock Tube.

UNIT III OBLIQUE SHOCK AND EXPANSION WAVES 10

Introduction – Oblique Shock Relations - Relation between θ and β- Shock Polar – Supersonic Flow over a Wedge - Weak Oblique Shocks – Supersonic Compression - Supersonic Expansion by Turning - The Prandtl-Meyer Expansion - Simple and Non-simple Regions.

UNIT IV MEASUREMENTS IN COMPRESSIBLE FLOW 10

Introduction - Pressure Measurements – Temperature Measurements - Velocity and Direction - Density Problems - Compressible Flow Visualization - High-Speed Wind Tunnels - Instrumentation and Calibration of Wind Tunnels.

UNIT V INTRODUCTION TO RAREFIED AND HIGH TEMPERATURE GAS DYNAMICS 5

Knudsen Number - Slip Flow Transition and Free Molecule Flow - Importance of High-Temperature Flows - Nature of High-Temperature Flows.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

Upon completion of this course, students will

CO1: Be able to solve the steady one dimensional compressible fluid flow problems.

CO2: Be provided with the knowledge on thermodynamic state of the gas behind normal shock waves.

CO3: Be provided with the knowledge on thermodynamic state of the gas behind oblique shock waves and expansion waves.

CO4: Be provided with the adequate knowledge on compressible flow measurements.

CO5: Be provided with the basic knowledge on rarefied and high temperature gas dynamics.

REFERENCES:

1. J.D. Anderson, Fundamentals of Aerodynamics, McGraw-Hill Education, 6th edition, 2017.
2. Rathakrishnan. E., Gas Dynamics, Prentice Hall of India, 7th edition, 2020.
3. Shapiro, AH, “Dynamics & Thermodynamics of Compressible Fluid Flow”, Ronald Press, 1982.
4. Houghton, EL and Caruthers, NB,“ Aerodynamics for Engineering Students”, Butterworth-Heinemann Series, 7th Edition 2017.
5. Zucrow, M.J, and Anderson, J.D, “Elements of gas dynamics” McGraw-Hill Book Co., New York, 1989.
6. Rae, WH and Pope, A, “Low speed Wind Tunnel Testing”, John Wiley Publications, 3rd edition, 1999.

CO	PO1	PO2	PO3	PO4	PO5	PO6
	1	**2**	**3**	**4**	**5**	**6**
CO1	2		3	2	2	2
CO2	2		3	2	2	2
CO3	2		3	2	2	2
CO4	2		3	2	2	2
CO5			3	2	2	2
	1.6	0	3	2	2	2

AO4072 FATIGUE AND FRACTURE MECHANICS L T P C

3 0 0 3

COURSE OBJECTIVES:

This course will make students

1. To learn the fundamentals aspects of fatigue & fracture mechanics.
2. To gain knowledge on the statistical aspects of fatigue behaviour of materials.
3. To get insights into the physical aspects of fatigue.
4. To evaluate the strength of the cracked bodies.
5. To provide knowledge on fatigue design and testing of aerospace structures.

UNIT I BASIC CONCEPTS & OVERVIEW 9

Historical Perspective – Case Studies – Review of Material Behaviour – Linear & Non-Linear Response – Temperature and Strain Rate Effect – Strain Hardening – Different Mechanisms of Failure – Typical Defects & Elements of Dislocation Theories – Atomic View of Fracture – Fractographic Examination of Failure Surfaces of Different Materials – Overview of Design Approach – Safe Life Design.

UNIT II FATIGUE OF STRUCTURES 9

S.N. curves – Endurance limit – Effect of mean stress – Goodman, Gerber and Soderberg relations and diagrams – Notches and stress concentrations – Stress concentration factors – Notched S-N curves – Low cycle and high cycle fatigue – Coffin-Manson's relation – Transition life – Cyclic Strain hardening and softening – Load History Analysis – Cycle counting techniques – Cumulative damage theory

UNIT III PHYSICAL ASPECTS OF FATIGUE 9

Fracture mechanism in metals - Phase in fatigue life – Crack source – Cleavage initiation – Crack growth – Ductile-brittle transition – Final fracture – Dislocations – Fatigue fracture surface of inter and intra-granular fracture – Environmental effects – Terminology and classification – Corrosion principles – Stress corrosion cracking – Hydrogen embrittlement – Influencing parameters on crack behaviour

UNIT IV LINEAR ELASTIC FRACTURE MECHANICS 9

Stress analysis and strength of a cracked body – Stress concentration – potential energy and surface energy – Energy release rate – Griffith's theory – Irwin extension of Griffith's theory to ductile materials – Plastic zone shape – Effect of thickness on fracture toughness – Stress intensity factors for typical geometries – Instability of the R-curve – K-controlled fracture – Plane strain fracture toughness – Mixed mode – Interaction of cracks – Limitations of the linear elastic fracture theory

UNIT V FRACTURE TOUGHNESS TESTING 9

General considerations for metallic specimens – Specimen configuration – Stress intensity factors – Pre-cracking – Grooving – ASTM E-399 and similar standards – K-R curve – J-testing on metals – Determination of crack parameters – CTOD testing – Testing of metals in the ductile-brittle transition region – Quantitative toughness tests – Charpy&Izod tests –- Mathematical modelling concepts

TOTAL: 45 PERIODS

COURSE OUTCOMES:

Upon completion of this course, students will be able

CO1: To identify and describe the basic fracture and fatigue mechanisms and apply that knowledge to failure analysis.

CO2: To correctly apply linear elastic fracture to predict material failure.

CO3: To predict lifetimes for fatigue and environmentally assisted cracking.

CO4: To demonstrate fatigue design and testing of structures.

CO5: To realise the importance of composite materials in Aerospace structures.

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
	1	**2**	**3**	**4**	**5**	**6**
CO1	1	1	1	1	1	1
CO2	2	2	1	2	2	1
CO3	3	2	1	3	3	1
CO4	2	2	1	2	2	1
CO5	2	2	1	2	2	1
	2	1.8	1	2	2	1

REFERENCES:

1. Barrois, W &Ripley,L, "Fatigue of Aircraft Structures", Pergamon Press, Oxford, 1983.
2. Brock,D, "Elementary Engineering Fracture Mechanics", Noordhoff International Publishing Co., London, 1994.
3. Knott,JF, "Fundamentals of Fracture Mechanics", Butterworth & Co. Ltd., London, 1983.
4. Sih,CG, "Mechanics of Fracture, Vol.1", Sijthoff and Noordhoff International Publishing Co., Netherland, 1989.

AO4078 VIBRATION ISOLATION AND CONTROL **L T P C**

3 0 0 3

COURSE OBJECTIVES:

This course will enables students

1. To get insight into the basic aspects of vibration theory.
2. To get in-depth knowledge on different types of isolators and its effectiveness.
3. To provide the basic knowledge on dynamic vibration absorber.
4. To realize the importance of materials selection for appropriate applications.
5. To get knowledge on the principles of active vibration control.

UNIT I BASIC VIBRATION THEORY 9

Free Vibration Theory – Determination of Natural Frequency of a Single Degree Of Freedom – System– Response of a Damped Single Degree of Freedom System – Role of Damping – Forced Vibrations of Discrete Systems – Continuous Systems – Vibrations of Beams and Shafts – Idealization of a Real System Into a Discrete Model – Resonance – An Overview of the Different Methods of Vibration Control

UNIT II VIBRATION ISOLATION 9

Transmissibility – Numerical Examples – Necessity of Vibration Isolation – Vibration Reduction at Source – System Redesign – Different Types of Isolators & Their Effectiveness – Pneumatic Suspension – Excitation Reduction at Source and Factors Affecting Vibration Level – Source Classification – Control of Flow Induced & Self-Excited Systems

UNIT III DYNAMIC VIBRATION ABSORBER 9

Dynamic Vibration Neutralizers – Self-tuned Pendulum Neutralizer - Optimum Design of Damped Absorbers – Absorber with ideal spring and viscous dashpot – Gyroscopic vibration absorbers – Impact Absorbers – Absorbers attached to continuous systems – Field Balancing of Rotors – Resonance: Detuning and Decoupling – Remedial Measures

UNIT IV SELECTION OF MATERIALS 9

Dynamic Properties of Viscoelastic Material – Selection of Materials – Damping-Stress Relationship – Selection Criteria for Linear Hysteretic Material – Design for enhanced material damping – Linear Viscoelastic Model – Constrained Layer Damping – Relaxation – Frequency and Temperature Dependence of the Complex Modulus – Overview and Role of Smart Materials

UNIT V PRINCIPLES OF ACTIVE VIBRATION CONTROL 9

Conceptual Understanding – Shape Memory Actuators for Vibration Control – Shape Memory Materials – Tuned Vibration Absorbers using SMA – Basics of Electro-and Magneto-Rheological Fluids – Active Vibration Isolation using ERF and MRF – Methods of Active Vibration Control Using Piezoelectric Materials – Derivation of Governing Equations – Response of the Structure.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

At the end of this course, students will be able

CO1: To realise the importance of vibration theory & its practical applications
CO2: To work out response calculations
CO3: To analyse and compare the different methods of vibration control
CO4: To exposure on vibration control using smart materials
CO5: To design a vibration control unit.

CO	PO1	PO2	PO3	PO4	PO5	PO6
	1	**2**	**3**	**4**	**5**	**6**
CO1	2	2	2	2	2	1
CO2	2	2	2	2	2	1
CO3	3	3	3	3	3	1
CO4	1	1	1	1	1	1
CO5	3	3	3	3	3	3
	2.2	2.2	2.2	2.2	2.2	1.4

REFERENCES:

1. Malcolm J. Crocker, "Handbook of Noise and Vibration Control", Wiley; 1st edition, 2007.
2. Mallik, AK, "Principles of Vibration Control",Affiliated East-West Press, India, 1990.
3. Mead,DJ, "Passive Vibration Control", Wiley, 1st edition, 1999.
4. Preumont,A"Vibration Control of Active Structures", Springer Netherlands, 3rd edition, 2011.

AO4074 NON-DESTRUCTIVE EVALUATION L T P C

3 0 0 3

COURSE OBJECTIVES:

This course will make students

1. To impart knowledge on the fundamentals of nondestructive testing methods and techniques, aircraft inspection methodology using NDT methods
2. To get insights into the basic aspects of electron microscopy.
3. To learn modern NDT techniques like acoustic emission, ultrasonic and thermographic testing methods.
4. To inspect the aircraft structures using NDT techniques.
5. To get basic knowledge on the structural health monitoring of aerospace structures.

UNIT I INTRODUCTION 9

Need for non-destructive evaluation (NDT) – Applications – Structural inspection – Structural deterioration due to corrosion and fatigue – Crack growth – Fabrication defects – Overloading – Detailed visual inspection – Aircraft wing and fuselage inspection using various NDT techniques – Overview and relative comparison of NDT methods – Jet engine inspection – Critical locations –

UNIT II ELECTRON MICROSCOPY 9

Fundamentals of optics – Optical microscope and its instrumental details – Variants in the optical microscopes and image formation – Polarization light effect – Sample preparation and applications of optical microscopes – Introduction to Scanning electron microscopy (SEM) – Instrumental details and image formation of SEM – Introduction to transmission electron microscopy (TEM) – Imaging techniques and spectroscopy – Sample preparation for SEM and TEM

UNIT III ACOUSTIC EMISSION AND ULTRASONICS 9

Sources of acoustic emission – Physical principals involving acoustic emission and ultrasonics – Configuration of ultrasonic sensors – Phased array ultrasonics – Instrument parts and features for acoustic emission and ultrasonics – Defect characterization – Inspection of cracks and other flaws in metals and composites – Interpretation of data – Image processing – Concepts and application

UNIT IV AIRCRAFT INSPECTION 9

Inspection Levels – General Visual Inspection – During pre, or post flight – Detailed Visual Inspection (DET) – Periodic inspection – Special Detailed Inspection (SDET) – Uses of NDT Methods – Jet Engine Inspection – Engine overhaul – Fluorescent penetrate inspection – Airframe Loading – Fuselage Inspection – Critical Locations – Comparison of different methods of NDT – Visual – Radiography – Eddy Current Testing – Liquid Penetrant Testing – Remote Testing - Landing Gear Inspection

UNIT V STRUCTURAL HEALTH MONITORING 9

An Overview of Structural Health Monitoring – Structural Health Monitoring and Role of Smart Materials – Structural Health Monitoring versus Non-Destructive Evaluation – A Broad Overview of Smart Materials Applications – Notable Applications of SHM in Aerospace Engineering – Structural health monitoring of composites – Repair investigation using SHM – Current limits and future trends.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

At the end of this course, students will be able

CO1: To realize the importance of various NDT techniques.
CO2: To identify suitable NDT technique for a particular application.
CO3: To demonstrate the physical principles involved in acoustic emission and ultrasonics.
CO4: Tohave knowledge on the physical principles involved in the various other techniques of NDT.
CO5: To realise the state-of-the-art in NDT testing and structural health monitoring.

CO	PO1	PO2	PO3	PO4	PO5	PO6
	1	2	3	4	5	6
CO1	1	1	1	2	1	1
CO2	1	1	1	2	1	1
CO3	2	1	2	2	2	1
CO4	1	1	1	2	1	1
CO5	1	1	1	2	1	1
	1.2	1	1.2	2	1.2	1

REFERENCES:

1. Cullity, BD & Stock, SR, “Elements of X-ray diffraction”, Prentice Hall, Inc. USA, 2001.
2. Daniel Balageas, Claus-Peter Fritzen, Alfredo Güemes, “Structural Health Monitoring”, Wiley-ISTE, 2006.
3. Douglas E Adams, “Health Monitoring of Structural Materials and Components-Methods with Applications”, John Wiley and Sons, 2007.
4. Douglas B. Murphy, “Fundamentals of light microscopy and electronic imaging”, Wiley-Liss, Inc. USA, 2001.
5. Richard Brundle. C, Charles A. Evans, Jr., Shaun Wilson, “Encyclopedia of Materials Characterization, Surfaces, Interfaces, Thin Films”, Butterworth-Heinemann, Boston, USA, 1992.

6. Williams, DB & Barry Carter,C, “Transmission electron microscopy, vol. 4”, Springer, USA, 1996.
7. Non-destructive Testing Handbook – ASNT Series – Volume 1 – 6.

AO4012 COMPONENT DESIGN OF AIRCRAFT ENGINES L T P C
3 0 0 3

COURSE OBJECTIVES:

1. This course provides the fundamental principles of fluid mechanics and thermodynamics on jet engine design.
2. This course brings out the differences in the design of various types of gas turbine engines.
3. This course imparts knowledge on the effect of inlet design on aerodynamic and propulsive aspects of aircrafts.
4. This course also addresses the problems associated with the design of combustion chambers.
5. This course deals with the practical difficulties in the matching of compressor and turbine.

UNIT I DESIGN FUNDAMENTALS OF GAS TURBINE ENGINE 8

Design Process - Constraint Analysis - Preliminary estimates - Aircraft weight and fuel consumption data- Mission analysis – Performance cycle analysis – Engine installation drag and sizing – Current challenges in gas turbine technology.

UNIT II INLET DESIGN 9

Elements of an Inlet - Engine Integration – Subsonic inlet - Engine Operational Requirements - Supersonic Inlet - Engine Operational Requirements - Engine Impact on Inlet Design - Inlet Impact on Engine Design- Validation of Inlet-Engine System.

UNIT III DESIGN OF ROTATING COMPONENTS 10

Fan and Compressor Aerodynamics - Diffusion factor - Aerofoil geometry - Flow path dimensions - Radial variation - Turbine Aerodynamics - Constant axial velocity – adiabatic - selected Mach number - Mean line stage Design - tage pressure ratio - Airfoil geometry - Radial variation - Turbine cooling - Engine life - Design Examples.

UNIT IV COMBUSTION CHAMBER DESIGN 10

Combustion system components- Chemical reactor theory - Combustor Stability map-Stirring and mixing-Total pressure loss-Fuels-Ignition-Combustion Systems of Main Burner Design: Air partitioning- Main burner component Design: Diffuser-types of burner-inner and outer casing Design-Fuel- nozzle-Dome and liner-Primary zone- swirler-Secondary holes-Dilution holes-Transition duct-Example Design calculation: Design of Afterburners-Design parameters-Components-Diffuser-Fuel injection-Ignition-Flame stabilization-Flame spread and after burner length-Example design calculations.

UNIT V EXHAUST NOZZLE DESIGN 8

Different types of Nozzles – design of nozzles - Jet control methods for reduction of infrared signature on military aircrafts - Simple design problem - One dimensional nozzle flow.

TOTAL: 45 PERIODS

COURSE OUTCOMES:
At the end of this course, students will be able
CO1: To successfully design a gas turbine engine for given requirements.
CO2: To have thorough knowledge with the operational behavior of the major components of gas turbine engines.
CO3: To identify the factors those limit the performance of the components of gas turbine engines.
CO4: To find solutions for the compressor and turbine matching in gas turbine engines.
CO5: To overcome the problems associated with inlet on aircrafts.

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
	1	**2**	**3**	**4**	**5**	**6**
CO1	3	1	3	3	3	1
CO2	1	1	1	1	1	1
CO3	2	1	1	1	1	1
CO4	1	1	1	1	1	1
CO5	1			1	1	
	1.6	0.8	1.2	1.4	1.4	0.8

REFERENCES:

1. Cumpsty,N, "Jet Propulsion: A Simple Guide to the Aerodynamics and Thermodynamics Design and Performance of Jet Engines", Cambridge University Press, 2nd edition, 2003.
2. Mattingly.JD,Heiser,WH and Pratt,DT,"Aircraft Engine Design", 2nd Edition, AIAA Education Series, 2002.
3. Oates. GC,"Aircraft Propulsion Systems Technology and Design", AIAA Education Series, 1989.
4. Saravanamuttoo, HIH andRogers,GFC,"Gas Turbine Technology", Pearson Education Canada, 6th edition, 2008.
5. Treager,IE,"Aircraft Gas Turbine Engine Technology", 3rd edition, Glencoe McGraw-Hill, Inc.1995.

AO4013 **AIRCRAFT SYSTEMS ENGINEERING** **L T P C**
` **3 0 0 3**

COURSE OBJECTIVES:
This course will make students
1. To provide exposure to basic concepts of Aircraft product system engineering and design
2. To provide exposure to different fault and failure analysis methods in aircraft systems.
3. To provide exposure on systems engineering process, System Architecture and integration
4. To provide exposure on the importance of Maintainability, reliability and availability of the product.
5. To provide exposure importance of formal planning and documentation in systems engineering.

UNIT I INTRODUCTION TO SYSTEMS ENGINEERING 9

Overview of Systems Engineering- Systems Engineering Concept Map-Systems Definition-The seven steps Systems Engineering-Conceptual System Design- System Engineering Process-Requirements and Management-Trade Studies-Integrated Product And Process Development.

UNITII THE AIRCRAFT SYSTEMS AND DESIGN 9

Introduction- Everyday Examples of Systems- Aircraft Systems –Generic Systems-Product Life Cycle- Different Phases-Whole Life Cycle Tasks- Systems Analysis-Design Drivers in the Project, Product, Operating Environment- Interfaces with the Subsystems-Mission analysis

UNIT III SYSTEM ARCHITECTURE SAND INTEGRATION 9

Introduction- Systems Architectures –Modeling and Trade-Offs Evolution of Avionics Architectures- Systems Integration Definition-Examples of Systems Integration-Integration Skills-Management of Systems Integration.

UNITIV PRACTICAL CONSIDERATIONS AND CONFIGURATION CONTROL 9

Stakeholders- Communications- Criticism- Configuration Control Process-Portrayal of a System-Varying Systems Configurations- Compatibility-Factors Affecting Compatibility–Systems Evolution. Considerations and Integration of Aircraft Systems- Risk Management.

UNITV SYSTEMS RELIABILITYAND MAINTAINABILITY 9

Systems and Components-Analysis- Influence, Economics, Design for Reliability-Fault and Failure Analysis-System Life Cycle cost-Case Study-Maintenance Types-Program-Planning and Design.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

Upon completion of this course, Students will be able to

CO1: Describe the importance of systems engineering process in product development

CO2: Categorize different aircraft systems and will be able to differentiate the avionics architectures

CO3: Outline the different stages of product development and factors influencing in each stage

CO4: Analyze the different alternatives during design process

CO5: Plan, organize and document the task related to product design, development and testing.

CO	PO1	PO2	PO3	PO4	PO5	PO6
	1	**2**	**3**	**4**	**5**	**6**
CO1		1	1	1	1	1
CO2				1	1	
CO3				1	1	
CO4	2	2	2	2	2	2
CO5	2	2	2	2	2	2
	0.8	1	1	1.4	1.4	1

REFERENCES:

1. Andrew P.Sage& James E.Armstrong, “Introduction to Systems Engineering”, 1st edition, 2000.
2. Erik Aslaksen& Rod Belcher, “Systems Engineering”, Prentice Hall, 1992.
3. Ian Moir&Allan Seabridge, “Design and Development of Aircraft Systems”, Wiley, 2nd edition, 2012.
4. Ian Moir& Allan Seabridge, “Aircraft Systems Mechanical, electrical, and avionics subsystems integration”, John Wiley &Sons Ltd, 2011.
5. Peter. Sydenham, “Systems Approach to Engineering Design”,Artechhouse,Inc,London, 2003.

A04014	AIRCRAFT DESIGN	L T P C 3 0 0 3

COURSE OBJECTIVES:

This course will enable students

1. To get in-depth knowledge about the preliminary concepts of aircraft design.
2. To provide with the basic knowledge on various aircraft loads.
3. To learn the design of aircraft wing.
4. To get exposed to different kinds of landing gear and its design.
5. To provide with the basic knowledge on integration of wing, fuselage, empennage and power plant.

UNIT I PRELIMINARY CONCEPTS 8

Aircraft Design Requirements - Specifications - Role of user - Aerodynamic and Structural considerations - Importance of weight fractions - Airworthiness requirements and standards - Classification of airplanes - Special features of an airplane- Airplane performance aspects - Range and endurance - Take-off and landing - Climbing performance - Engine Performance

UNIT II AIRCRAFT LOADS 10

Ground loads - Flight Loads - Symmetrical loads in flight - Basic flight loading conditions - Load factor calculation during a manouever - Velocity - Load factor diagram - Gust load and its estimation - Structural limits - Airplane weight estimation based on type of airplane - Trends in wing loading - Weight-estimation based on mission requirements - iterative approach - Span wise load distribution - Wing Loading

UNIT III WING DESIGN 10

Selection of airfoil selection - Influencing factors - Planform shapes of an airplane wing - Stalling, takeoff and landing considerations - Wing drag estimation - High lift devices - Supercritical Airfoils - Cockpit and aircraft passenger cabin layout for different aircraft - types of associated structure - structural layout - features of light airplanes using advanced composite materials - Structural design aspects - Bending moment and shear force diagram for wing and fuselage - Design principles of all metal stressed skin construction for civil and military applications

UNIT IV LANDING GEAR 8

Different kinds of landing gears and associated arrangement for civil and military airplanes - Preliminary calculations for locating main and nose landing gears - Integration of Structure and Power Plant - Estimation of Horizontal and Vertical tail volume ratios - Choice of power plant and various options of locations - Considerations of appropriate air-intakes- Power Plant Loading

UNIT V INTEGRATION OF WING, FUSELAGE, EMPENNAGE AND POWER PLANT 9

Estimation of center of gravity - Introduction to advanced concepts - Aircraft Stability - Relaxed static stability - Controlled configured vehicles - V/STOL aircraft & rotary wing vehicles - Design and layout of flying controls and engine controls - Design of a wing-fuselage joint

TOTAL: 45 PERIODS

COURSE OUTCOMES:

At the end of this course, students will

CO1: Haveoverall knowledge of preliminary aircraft design.

CO2: Havebasic knowledge of aircraft rules and airworthiness requirements imposed by governing bodies.

CO3: Be able to calculate and estimate aircraft loads under different loading conditions.

CO4: Be able to configure an aircraft wing based on aerodynamic considerations.

CO5: Be exposed the role of aircraft stability in the aircraft design process.

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
	1	**2**	**3**	**4**	**5**	**6**
CO1	1	1	1	1	1	
CO2		1	1			
CO3	2	1	2	2	1	1
CO4	1	1	1	1	1	
CO5		1	1	1		
	0.8	1	1.2	1	0.6	0.2

REFERENCES:

1. Conway, HG, “Landing Gear Design”, Chapman & Hall; 1st edition, 1958.
2. Daniel P Raymer, “Aircraft Design: A conceptual approach”, AIAA Educational Series, 5th edition 2012.
3. DarrolStinton ,“The Design of Airplane”, Wiley publishers,, 2nd edition, 2001.
4. John D Anderson,“Airplane Performance and Design”, McGraw Hill, 1st edition,1999.
5. Nicholai,LM, “Fundamentals of airplane Design”, Univ. of Dayton DHIO, 1975.
6. Torenbeek, Egbert, “Synthesis of Subsonic Airplane Design”, Springer publishers, 1982.

AO4015	**COMPOSITE PRODUCT PROCESSING METHODS**	**L**	**T**	**P**	**C**
		3	**0**	**0**	**3**

COURSE OBJECTIVES:

This course will make students

1. To impart knowledge on the material selection for fabricating composite products.
2. To impart an idea about the product development and manufacturing of composites.
3. To acquire adequate knowledge about the manufacturing of thermoset composites.
4. To acquire adequate knowledge about the manufacturing of thermoplastic composites.
5. To gain knowledge on joining, machining and cutting of composites.

UNIT I MATERIAL SELECTION 9

Reinforcements - Glass Fiber Manufacturing - Carbon Fiber Manufacturing - Aramid Fiber Manufacturing - Matrix Materials - Thermoset Resins - Thermoplastic Resins - Fabrics - Prepregs - Preforms - Molding Compound - Honeycomb and Other Core Materials - The Need for Material Selection - Reasons for Material Selection - Material Property Information - Steps in the Material Selection Process - Material Selection Methods.

UNIT II PRODUCT DEVELOPMENT AND DESIGN FOR MANUFACTURING 9

Product Development Process - Reasons for Product Development - Importance of Product Development - Concurrent Engineering - Product Life Cycle - Phases of Product Development - Design Review - Failure Modes and Effects Analysis (FMEA) - Design Problems - DFM - DFM Implementation Guidelines - Design Evaluation Method - Design for Assembly (DFA).

UNIT III MANUFACTURING PROCESSES FOR THERMOSET COMPOSITES 9

Prepreg Lay-Up Process - Wet Lay-Up Process - Spray-Up Process - Filament Winding Process - Pultrusion Process - Resin Transfer Molding Process - Structural Reaction Injection Molding (SRIM) Process - Compression Molding Process - Roll Wrapping Process - Injection Molding of Thermoset Composites.

UNIT IV MANUFACTURING PROCESSES FOR THERMOPLASTIC COMPOSITES 9

Thermoplastic Tape Winding - Thermoplastic Pultrusion Process - Compression Molding of GMT - Hot Press Technique - Autoclave Processing - Diaphragm Forming Process - Injection Molding.

UNIT V JOINING, MACHINING AND CUTTING OF COMPOSITES 9

Adhesive Bonding - Failure Modes in Adhesive Bonding - Basic Science of Adhesive Bonding - Types of Adhesives - Advantages of Adhesive Bonding over Mechanical Joints - Disadvantages of Adhesive Bonding - Adhesive Selection Guidelines - Surface Preparation Guidelines - Design Guidelines for Adhesive Bonding- Theoretical Stress Analysis for Bonded Joints - Mechanical Joints - Preparation for the Bolted Joint-Purposes of Machining - Challenges during Machining of Composites - Failure Mode during Machining of Composites - Cutting Tools - Types of Machining Operations - Cutting Operation - Drilling Operation.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

Upon completion of this course, students will be able

CO6: To select the suitable material for making composite products.

CO7: To gain knowledge on product development and manufacturing of composites.

CO8: To select the most appropriate manufacturing process for fabricating thermoset composite components.

CO9: To select the most appropriate manufacturing process for fabricating thermoplastic composite components.

CO10: To gain knowledge about the joining, machining and cutting of composites.

REFERENCES:

1. Allen Baker, “Composite Materials for Aircraft Structures”, AIAA Series, 2nd Edition, 2004.
2. Autar K Kaw, “Mechanics of Composite Materials”, CRC Press, 2nd edition, 2005.
3. Lubing, “Handbook on Advanced Plastics and Fibre Glass”, Von Nostran Reinhold Co., New York, 1989.
4. Sanjay K. Mazumdar, “Composites Manufacturing : Materials, Product, and Process Engineering”, CRC Press, Washington, D.C, 2002.

CO	PO1	PO2	PO3	PO4	PO5	PO6
	1	**2**	**3**	**4**	**5**	**6**
CO1			2		1	1
CO2			2		1	1
CO3			2		1	1
CO4			2		1	1
CO5			2		1	1
	0	0	2	0	1	1

AO4016 HELICOPTER AERODYNAMICS

L T P C
3 0 0 3

COURSE OBJECTIVES:

1. This course will make students to provide with introductory concepts of types of rotorcraft.
2. This course imparts knowledge on the fundamental aspects of helicopter aerodynamics and performance of helicopters.
3. This course will provide basic knowledge on the performance of helicopters.
4. This course presents stability and control aspects of helicopters.
5. This course will explorethe basic aerodynamic design aspects of helicopters.

UNIT I INTRODUCTION 9

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 10

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 9

Blade section design, Blade tip shapes, Drag estimation – Rear fuselage upsweep, vibration problem of Helicopter blades.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

Upon completion of this course, students will be able to

CO1: Describe and compare possible helicopter structures and configurations.
CO2: Identify features of aerodynamic components of rotary wing aircraft and its performance.
CO3: Describe the aerodynamic characteristics that affect rotary wing flight.
CO4: Idea about the factors that influence helicopter stability.
CO5: Gain knowledge of helicopter controls and vibration analysis of helicopter blades.

CO	PO1	PO2	PO3	PO4	PO5	PO6
	1	**2**	**3**	**4**	**5**	**6**
CO1	2	1	1	1	1	
CO2					2	1
CO3		1		1	1	
CO4	1	1	1	1	1	1
CO5	1	1	1	1	1	1
	0.8	0.8	0.6	0.8	1.2	0.6

REFERENCES:

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

AO4073 HIGH SPEED JET FLOWS L T P C
3 0 0 3

COURSE OBJECTIVES:

This course will make students

1. To get insight into the basic aspects of jets and types of jets.
2. To learn the basic properties of jets and its characteristics.
3. To get knowledge on various active and passive jet control methods.
4. To gain knowledge into the basic aspects of jet acoustics
5. To acquire in-depth knowledge on how and what type of control methods can be implemented practically.

UNIT I INTRODUCTION 9

Properties of Turbulent Jets-Fundamental Concepts, Submerged Jets- Velocity Profiles in a Submerged Jet- Spread of a turbulent submerged jet- Lines of Constant Velocity in a Submerged Jet. Velocity Variation along the Axis of a Submerged jet, Velocity, Temperature, and Concentration Profiles in a Turbulent Jet Spreading into an External Stream of Fluid- Spread of a Turbulent Jet into a Co-flowing or Counter-flowing External Stream- Turbulence Characteristics in a Free Jet.

UNIT II JETS 9

Types of Jets-Plane free-jets. Round jets. Plane jets in a co-flowing stream. Round jet in Co flowing stream- Swirling jets-Radial jets- Wall jets- Jet Characteristics & Entrainment, Mathematical treatment of jet profiles- Semi-empirical Theories. Mixing Layers- Computational and Experimental Techniques for Studying the Jets.

UNIT III ACTIVE JETCONTROL METHODS 9

Active control methods- Actuators-Fluidic, Thermal, Acoustic, Piezoelectric, Electromagnetic, MEMS,Synthetic Jets, Controls and Sensors, Applications.

UNIT IV PASSIVE JET CONTROL METHODS 9

Passive control techniques- Tabs, Grooves, Chevrons, non-circular nozzles, Notches & wires, vortex generators.Optical Flow Visualization, Applications.

UNIT V JET ACOUSTICS 9

Introduction to Jet Acoustics – Types of jet noise – Source of generation- Travelling wave solution,standing wave solution – multi-dimensional acoustics-Theoretical Concepts of Jet Noise Generation and Suppression–Jet Noise suppression techniques – applications

TOTAL: 45 PERIODS

COURSE OUTCOMES:

Upon completion of this course, students will be able

CO1: To acquire knowledge on the unique features of jet flows.
CO2: To analyse the characteristics of jets.
CO3: To havethrough knowledge on active and passive control methods of jets.
CO4: To acquire knowledge on jet acoustics and methods for suppression of jet noise.
CO5: To demonstrate various experimental techniques to determine jet characteristics.

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
	1	**2**	**3**	**4**	**5**	**6**
CO1			2		3	1
CO2	3		2	2	3	1
CO3			2	1	3	1
CO4			2		3	1
CO5	2		2	3	3	1
	1	0	2	1.2	3	1

REFERENCES:

1. EthirajanRathakrishnan, “Applied Gas Dynamics”, John Wiley, New York, 2010.
2. Liepmann and Roshko, “Elements of Gas Dynamics”, Dover Publishers, 2017.
3. Rathakrishnan E., “Gas Dynamics”, Prentice Hall of India, New Delhi, 5th edition, 2014.
4. Shapiro, AH, “Dynamics and Thermodynamics of Compressible Fluid Flow, Vols. I & II”, Ronald Press, New York, 1953.

AO4075 SMART MATERIALS AND STRUCTURAL HEALTH MONITORING L T P C
3 0 0 3

COURSE OBJECTIVES:

This course will enables students

1. To get basic idea on the fundamentals of structural health monitoring.
2. To impart knowledge in the areas of vibration based techniques in structural health monitoring, fibre optics and piezo electric sensors.
3. To gain knowledge on the fundamentals of fabrication, modelling, analysis, and design of smart materials and structures.
4. To get exposed to the state of the art of smart materials and systems,
5. To impart knowledge on spanning piezoelectrics, shape memory alloys, electro active polymers, mechanochromic materials and fibre optics.

UNIT I STRUCTURAL HEALTH MONITORING 8

An Overview of Structural HealthMonitoring, Structural Health Monitoring and Smart Materials, Structural Health Monitoring versus Non Destructive Evaluation A broad Overview of Smart Materials Overview of Application Potential of SHM Notable Applications of SHM – Aerospace Engineering. Structural health monitoring of composites – Repair investigation using SHM.

UNIT II OVERVIEW OF SMART MATERIALS 10

Introduction to Smart Materials, Principles of Piezoelectricity, Perovskyte Piezoceramic Materials, Single Crystals vs Polycrystalline Systems, Piezoelectric Polymers, Principles of Magnetostriction, Rare earth Magnetostrictive materials, Giant Magnetostriction and Magneto-resistance Effect, Introduction to Electro-active Materials, Electronic Materials, Electro-active Polymers, Ionic Polymer Matrix Composite (IPMC), Shape Memory Effect, Shape Memory Alloys, Shape Memory Polymers, Electro-rheological Fluids, Magneto Rheological Fluids.

UNIT III SMART COMPOSITES 10

Review of Composite Materials, Micro and Macro-mechanics, Modelling Laminated Composites based on Classical Laminated Plate Theory, Effect of Shear Deformation, Dynamics of Smart Composite Beam, Governing Equation of Motion, Finite Element Modelling of Smart Composite Beams , Vibration Control using SHM –introduction to FE formulation Constitutive Relationship - Element Stiffness Matrix for High Precision Finite Element -Element Mass Matrix for High Precision Finite Element - Developing Actuator and Sensor Influence Matrix .Delamination Sensing using Piezo Sensory Layer.

UNIT IV INTELLIGENT SYSTEMS AND NEURAL NETWORKS 9

Operational evaluation -.Data acquisition- Feature extraction-Statistical model development for feature discrimination -Data Cleansing – Normalization-Data Fusion – Compression – Statistical model building - Supervised pattern recognition - Unsupervised pattern recognition – Signal processing – Fuzzy C means- K means – Kohenon's Self organization mapping- Fundamentals of Wavelet analysis –Life Prediction.

UNIT V ADVANCES IN SMART STRUCTURES &MATERIALS 8

Self-Sensing Piezoelectric Transducers,Energy Harvesting Materials, Autophagous Materials, Self-Healing Polymers, Intelligent System Design, Emergent System Design of Chemical and Bio-Chemical sensing in structural Assessment – Absorptive chemical sensors – Spectroscopes – Fibre Optic Chemical Sensing Systems and Distributed measurement.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

Upon completion of this course, students will be able

CO1: To familiarize with the fundamentals of history of SHM.
CO2: To provide a systematic approach to SHM process.
CO3: To have knowledge of the various smart materials used for aerospace applications.
CO4: To familiarize with the non-destructive test techniques relevant to SHM.
CO5: To provide hands-on experience with experimental modal analysis.

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
	1	**2**	**3**	**4**	**5**	**6**
CO1	3		3		1	1
CO2			2		1	1
CO3			2		1	1
CO4	3		3		1	1
CO5			2		2	1

REFERENCES:
1. Brian Culshaw, “Smart Structures,and Materials”, Artech House, 2000.
2. DanielBalageas, Claus-Peter Fritzen, Alfredo Güemes, “Structural Health Monitoring”, Wiley - ISTE, 2006.
3. Douglas E Adams, “Health Monitoring of Structural Materials and Components-Methods with Applications”, John Wiley and Sons, 2007.
4. Gandhi and Thompson,“Smart Materials and Structures”, Springer Netherlands, 1992.
5. LaureneFausett, **“**Fundamentals Of Neural Networks”,Pearson publishers, 1994
6. Victor Giurglutiu, “Structural Health Monitoring with Wafer Active Sensors”, Academic Press Inc, 2007.

AO4071 ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING L T P C

3 0 0 3

OBJECTIVES:
1. To gain knowledge on artificial intelligence.
2. To understand the concepts of Machine Learning.
3. To appreciate supervised learning and their applications.
4. To appreciate the concepts and algorithms of unsupervised learning.
5. To understand the theoretical and practical aspects of Probabilistic Graphical Models.

UNIT I ARTIFICIALINTELLIGENCE 9

Artificial intelligence – Basics – Goals of artificial intelligence– AItechniques–problem representation in AI – Problem reduction and solution techniques - Application of AI and KBES in Robots.

UNIT II INTRODUCTION TO MACHINELEARNING 9

Machine Learning–Types of Machine Learning –Machine Learning process- preliminaries, testing Machine Learning algorithms, turning data into Probabilities, and Statistics for Machine Learning-Probability theory – Probability Distributions – Decision Theory.

UNIT III SUPERVISED LEARNING 9

Linear Models for Regression – Linear Models for Classification- Discriminant Functions, Probabilistic Generative Models, Probabilistic Discriminative Models – Decision Tree Learning – Bayesian Learning, Naïve Bayes – Ensemble Methods, Bagging, Boosting, Neural Networks, Multi-layer Perceptron, Feed- forward Network, Error Back propagation - Support Vector Machines.

UNIT IV UNSUPERVISEDLEARNING 9

Clustering- K-means – EM Algorithm- Mixtures of Gaussians –Dimensionality Reduction, Linear Discriminant Analysis, Factor Analysis, Principal Components Analysis, Independent Components Analysis.

UNIT V PROBABILISTIC GRAPHICAL MODELS 9

Graphical Models – Undirected Graphical Models – Markov Random Fields – Directed Graphical Models –Bayesian Networks – Conditional Independence properties – Markov Random Fields-Hidden Markov Models – Conditional Random Fields (CRFs).

TOTAL: 45 PERIODS

OUTCOMES:

On Completion of the course the student will be able to

- Optimize the robots using Artificial Intelligence.
- Design a learning model appropriate to the application.
- ImplementProbabilisticDiscriminativeandGenerativealgorithmsforanapplicationofyourchoiceandanalyzet he results.
- Use a tool to implement typical Clustering algorithms for different types of applications.
- Identifyapplicationssuitablefordifferenttypesof Machine Learningwithsuitablejustification.

CO	PO					
	1	2	3	4	5	6
1	2	1	1	2	1	1
2	2	1	1	2	1	1
3	2	1	1	2	1	1
4	2	1	1	2	1	1
5	2	1	1	2	1	1
AVG	2	1	1	2	1	1

1-low, 2-medium, 3-high, '-"- no correlation

REFERENCES:

1. ChristopherBishop,"PatternRecognitionandMachineLearning"Springer,2007.
2. Stephen Marsland, "Machine Learning – An Algorithmic Perspective", Chapman andHall,CRCPress,SecondEdition,2014.
3. KevinP.Murphy,"MachineLearning:AProbabilisticPerspective",MITPress,2012.
4. EthemAlpaydin,"Introduction to Machine Learning",MIT Press,ThirdEdition,2014.
5. TomMitchell,"MachineLearning",McGraw-Hill,1997.

AO4017 AIRCRAFT GUIDANCE AND CONTROL L T P C
3 0 0 3

COURSE OBJECTIVES:

This course will make students

1. To learn about the aircraft equations of motion and method of linearization.
2. Toimpart knowledge on the operating principle of guidance law.
3. To gain knowledge onvarious augmentation systems.
4. To get familiarize with the concepts of longitudinal stability and to design the longitudinal autopilot.
5. To study lateral stability and to design the lateral autopilot.

UNIT I INTRODUCTION 8

Introduction to Guidance and control-Definition, Historical background – Coordinate Frame - Equations of motion – Linearization

UNIT II AUGMENTATION SYSTEMS 8

Need for automatic flight control systems, Stability augmentation systems, control augmentation systems, Design of Limited authority and Full Authority Augmentation systems - Gain scheduling concepts.

UNITIII LONGITUDINALAUTOPILOT 9

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.

UNITIV LATERAL AUTOPILOT 10

Damping of the Dutch Roll, Methods of Obtaining Coordination, Yaw Orientation Control system, turn compensation, AutomaticlateralBeamGuidance.IntroductiontoFly-by-wireflightcontrol systems, Lateral control law design using back stepping algorithm.

UNITV MISSILEAND LAUNCHVEHICLEGUIDANCE 10

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

TOTAL: 45PERIODS

COURSE OUTCOMES:

Upon completion of this course students will be able to

CO1: Explain the equations governing the aircraft dynamics and the process of linearizing them.

CO2: Define the various guidance schemes & requirements for aircrafts and missiles.

CO3: Explain the principle of stability and control augmentation systems.

CO4: Explain the oscillatory modes and methods of suppressing them

CO5: Design the controller for lateral, longitudinal and directional control of aircrafts.

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
	1	**2**	**3**	**4**	**5**	**6**
CO1	2	2	1	2	2	1
CO2	1	1	1	1	1	1
CO3	2	2	2	2	2	1
CO4	2	2	2	2	2	1
CO5	3	3	3	3	3	3
	2	2	1.8	2	2	1.4

REFERENCES:

1. BlakeLock,JH, “AutomaticcontrolofAircraftandmissiles”,JohnWileySons,NewYork, 1990.
2. CollinsonRPG,“IntroductiontoAvionics”,ChapmanandHall,India,1996.
3. Garnel.P&EastDJ, “GuidedWeaponcontrolsystems”,PergamonPress,Oxford, 1977.
4. Michael V Cook, “Flight Dynamics Principles: A Linear Systems Approach to Aircraft Stability and Control”, Elsevier, 2013.
5. NelsonRC, “Flightstability&AutomaticControl”,McGrawHill,1989.
6. Pierre T. Kabamba, Anouck R. Girard, “Fundamentals of Aerospace Navigation and Guidance”, Cambridge university press, 2014.
7. Stevens BL and Lewis FL, “Aircraft control &simulation”,JohnWileySons, NewYork,1992.
8. Thomas R Yechout, Steven L Morris, David E Bossert, Wayne F Hallgren, James K Hall, “Introduction to Aircraft Flight Mechanics”, AIAA Education series, 2014.

AUDIT COURSES

AX4091 ENGLISH FOR RESEARCH PAPER WRITING **L T P C**
2 0 0 0

OBJECTIVES

- Teach how to improve writing skills and level of readability
- Tell about what to write in each section
- Summarize the skills needed when writing a Title
- Infer the skills needed when writing the Conclusion
- Ensure the quality of paper at very first-time submission

UNIT I INTRODUCTION TO RESEARCH PAPER WRITING 6
Planning and Preparation, Word Order, Breaking up long sentences, Structuring Paragraphs and Sentences, Being Concise and Removing Redundancy, Avoiding Ambiguity and Vagueness

UNIT II PRESENTATION SKILLS 6
Clarifying Who Did What, Highlighting Your Findings, Hedging and Criticizing, Paraphrasing and Plagiarism, Sections of a Paper, Abstracts, Introduction

UNIT III TITLE WRITING SKILLS 6
Key skills are needed when writing a Title, key skills are needed when writing an Abstract, key skills are needed when writing an Introduction, skills needed when writing a Review of the Literature, Methods, Results, Discussion, Conclusions, The Final Check

UNIT IV RESULT WRITING SKILLS 6
Skills are needed when writing the Methods, skills needed when writing the Results, skills are needed when writing the Discussion, skills are needed when writing the Conclusions

UNIT V VERIFICATION SKILLS 6
Useful phrases, checking Plagiarism, how to ensure paper is as good as it could possibly be the first- time submission

TOTAL: 30 PERIODS

OUTCOMES

CO1 –Understand that how to improve your writing skills and level of readability
CO2 – Learn about what to write in each section
CO3 – Understand the skills needed when writing a Title
CO4 – Understand the skills needed when writing the Conclusion
CO5 – Ensure the good quality of paper at very first-time submission

REFERENCES

1. Adrian Wallwork , English for Writing Research Papers, Springer New York Dordrecht Heidelberg London, 2011
2. Day R How to Write and Publish a Scientific Paper, Cambridge University Press 2006
3. Goldbort R Writing for Science, Yale University Press (available on Google Books) 2006
4. Highman N, Handbook of Writing for the Mathematical Sciences, SIAM. Highman's book 1998.

AX4092 DISASTER MANAGEMENT

	L	T	P	C
	2	**0**	**0**	**0**

OBJECTIVES

- Summarize basics of disaster
- Explain a critical understanding of key concepts in disaster risk reduction and humanitarian response.
- Illustrate disaster risk reduction and humanitarian response policy and practice from multiple perspectives.
- Describe an understanding of standards of humanitarian response and practical relevance in specific types of disasters and conflict situations.
- Develop the strengths and weaknesses of disaster management approaches

UNIT I INTRODUCTION 6

Disaster: Definition, Factors and Significance; Difference between Hazard And Disaster; Natural and Manmade Disasters: Difference, Nature, Types and Magnitude.

UNIT II REPERCUSSIONS OF DISASTERS AND HAZARDS 6

Economic Damage, Loss of Human and Animal Life, Destruction Of Ecosystem. Natural Disasters: Earthquakes, Volcanisms, Cyclones, Tsunamis, Floods, Droughts And Famines, Landslides And Avalanches, Man-made disaster: Nuclear Reactor Meltdown, Industrial Accidents, Oil Slicks And Spills, Outbreaks Of Disease And Epidemics, War And Conflicts.

UNIT III DISASTER PRONE AREAS IN INDIA 6

Study of Seismic Zones; Areas Prone To Floods and Droughts, Landslides And Avalanches; Areas Prone To Cyclonic and Coastal Hazards with Special Reference To Tsunami; Post-Disaster Diseases and Epidemics

UNIT IV DISASTER PREPAREDNESS AND MANAGEMENT 6

Preparedness: Monitoring Of Phenomena Triggering a Disaster or Hazard; Evaluation of Risk: Application of Remote Sensing, Data from Meteorological And Other Agencies, Media Reports: Governmental and Community Preparedness.

UNIT V RISK ASSESSMENT 6

Disaster Risk: Concept and Elements, Disaster Risk Reduction, Global and National Disaster Risk Situation. Techniques of Risk Assessment, Global Co-Operation in Risk Assessment and Warning, People's Participation in Risk Assessment. Strategies for Survival

TOTAL : 30 PERIODS

OUTCOMES

CO1: Ability to summarize basics of disaster

CO2: Ability to explain a critical understanding of key concepts in disaster risk reduction and humanitarian response.

CO3: Ability to illustrate disaster risk reduction and humanitarian response policy and practice from multiple perspectives.

CO4: Ability to describe an understanding of standards of humanitarian response and practical relevance in specific types of disasters and conflict situations.

CO5: Ability to develop the strengths and weaknesses of disaster management approaches

REFERENCES

1. Goel S. L., Disaster Administration And Management Text And Case Studies",Deep & Deep Publication Pvt. Ltd., New Delhi,2009.
2. NishithaRai, Singh AK, "Disaster Management in India: Perspectives, issues and strategies "'NewRoyal book Company,2007.
3. Sahni, PardeepEt.Al. ," Disaster Mitigation Experiences And Reflections", Prentice Hall of India, New Delhi,2001.

AX4093 **CONSTITUTION OF INDIA** **L T P C**
2 0 0 0

OBJECTIVES

Students will be able to:

- Understand the premises informing the twin themes of liberty and freedom from a civil rights perspective.
- To address the growth of Indian opinion regarding modern Indian intellectuals' constitutional Role and entitlement to civil and economic rights as well as the emergence nation hood in the early years of Indian nationalism.
- To address the role of socialism in India after the commencement of the Bolshevik Revolutionin1917and its impact on the initial drafting of the Indian Constitution.

UNIT I HISTORY OF MAKING OF THE INDIAN CONSTITUTION
History, Drafting Committee, (Composition & Working)

UNIT II PHILOSOPHY OF THE INDIAN CONSTITUTION
Preamble, Salient Features

UNIT III CONTOURS OF CONSTITUTIONAL RIGHTS AND DUTIES
Fundamental Rights, Right to Equality, Right to Freedom, Right against Exploitation, Right to Freedom of Religion, Cultural and Educational Rights, Right to Constitutional Remedies, Directive Principles of State Policy, Fundamental Duties.

UNIT IV ORGANS OF GOVERNANCE
Parliament, Composition, Qualifications and Disqualifications, Powers and Functions, Executive, President, Governor, Council of Ministers, Judiciary, Appointment and Transfer of Judges, Qualifications, Powers and Functions.

UNIT V LOCAL ADMINISTRATION
District's Administration head: Role and Importance, Municipalities: Introduction, Mayor and role of Elected Representative, CEO, Municipal Corporation. Pachayati raj: Introduction, PRI: Zila Pachayat. Elected officials and their roles, CEO Zila Pachayat: Position and role. Block level: Organizational Hierarchy(Different departments), Village level:Role of Elected and Appointed officials, Importance of grass root democracy.

UNIT VI ELECTION COMMISSION
Election Commission: Role and Functioning. Chief Election Commissioner and Election Commissioners - Institute and Bodies for the welfare of SC/ST/OBC and women.

TOTAL: 30 PERIODS

OUTCOMES

Students will be able to:

- Discuss the growth of the demand for civil rights in India for the bulk of Indians before the arrival of Gandhi in Indian politics.
- Discuss the intellectual origins of the framework of argument that informed the conceptualization
- of social reforms leading to revolution in India.
- Discuss the circumstances surrounding the foundation of the Congress Socialist Party[CSP] under the leadership of Jawaharlal Nehru and the eventual failure of the proposal of direct elections through adult suffrage in the Indian Constitution.
- Discuss the passage of the Hindu Code Bill of 1956.

SUGGESTED READING

- The Constitution of India,1950(Bare Act),Government Publication.
- Dr.S.N.Busi, Dr.B. R.Ambedkar framing of Indian Constitution,1st Edition, 2015.
- M.P. Jain, Indian Constitution Law, 7th Edn., Lexis Nexis,2014.
- D.D. Basu, Introduction to the Constitution of India, Lexis Nexis, 2015.

AX4094 **<u>நற்றமிழ் இலக்கியம்</u>** **L T P C**
2 0 0 0

UNIT I **சங்க இலக்கியம்** **6**

1. தமிழின் துவக்க நூல் தொல்காப்பியம்

– எழுத்து, சொல், பொருள்

2. அகநானூறு (82)

- இயற்கை இன்னிசை அரங்கம்

3. குறிஞ்சிப் பாட்டின் மலர் க்காட்சி

4. புறநானூறு (95,195)

- போரை நிறுத்திய ஔவையார்

UNIT II **அறநெறித் தமிழ்** **6**

1. அறநெறி வகுத்த திருவள்ளுவர்

- அறம் வலியுறுத்தல், அன்புடைமை, ஒப்புரவறிதல், ஈகை, புகழ்

2. பிற அறநூல்கள் - இலக்கிய மருந்து

– ஏலாதி, சிறுபஞ்சமூலம், திரிகடுகம், ஆசாரக்கோவை (தூய்மையை வலியுறுத்தும் நூல்)

UNIT III **இரட்டைக் காப்பியங்கள்** **6**

1. கண்ணகியின் புரட்சி
   - சிலப்பதிகார வழக்குரை காதை
2. சமூகசேவை இலக்கியம் மணிமேகலை
   - சிறைக்கோட்டம் அறக்கோட்டமாகிய காதை

UNIT IV **அருள்நெறித் தமிழ்** **6**

1. சிறுபாணாற்றுப்படை
   - பாரி முல்லைக்குத் தேர் கொடுத்தது,
   பேகன் மயிலுக்குப் போர் வைகொடுத்தது, அதியமான் ஔவைக்கு நெல்லிக்கனி கொடுத்தது, அரசர் பண்புகள்
2. நற்றிணை
   - அன்னைக்குரிய புன்னை சிறப்பு
3. திருமந்திரம் (617, 618)
   - இயமம் நியமம் விதிகள்
4. தர்மச்சாலையை நிறுவிய வள்ளலார்
5. புறநானூறு
   - சிறுவனே வள்ளலானான்
6. அகநானூறு (4) - வண்டு
   நற்றிணை (11) - நண்டு
   கலித்தொகை (11) - யானை, புறா
   ஐந்திணை 50 (27) - மான்
   ஆகியவை பற்றிய செய்திகள்

UNIT V **நவீன தமிழ் இலக்கியம்** **6**

1. உரைநடைத் தமிழ்,
   - தமிழின் முதல் புதினம்,
   - தமிழின் முதல் சிறுகதை,
   - கட்டுரை இலக்கியம்,
   - பயண இலக்கியம்,
   - நாடகம்,
2. நாட்டு விடுதலை போராட்டமும் தமிழ் இலக்கியமும்,
3. சமுதாய விடுதலையும் தமிழ் இலக்கியமும்,
4. பெண் விடுதலையும் விளிம்பு நிலையினரின் மேம்பாட்டில் தமிழ் இலக்கியமும்,
5. அறிவியல் தமிழ்,
6. இணையத்தில் தமிழ்,
7. சுற்றுச்சூழல் மேம்பாட்டில் தமிழ் இலக்கியம்.

TOTAL: 30 PERIODS

<u>தமிழ் இலக்கிய வெளியீடுகள் / புத்தகங்கள்</u>

1. தமிழ் இணைய கல்விக்கழகம் (Tamil Virtual University)

   - www.tamilvu.org

2. தமிழ் விக்கிப்பீடியா (Tamil Wikipedia)
-https://ta.wikipedia.org
3. தர் மபுர ஆதீன வெளியீடு
4. வாழ்வியல் களஞ்சியம்
   - தமிழ்ப் பல்கலைக்கழகம், தஞ்சாவூர்
5. தமிழ்கலைக் களஞ்சியம்
   - தமிழ் வளர் ச் சித்துறை (thamilvalarchithurai.com)
6. அறிவியல் களஞ்சியம்
   - தமிழ்ப் பல்கலைக்கழகம், தஞ்சாவூர்