ANNA UNIVERSITY, CHENNAI
AFFILIATED INSTITUTIONS
REGULATIONS 2013
M.E. AERONAUTICAL ENGINEERING
I TO IV SEMESTERS (FULL TIME) CURRICULUM AND SYLLABUS

SEMESTER I

SL. NO	COURSE CODE	COURSE TITLE	L	T	P	C
THEORY						
1.	MA7170	Advanced Mathematical Methods	3	1	0	4
2.	AO7101	Aerodynamics	3	1	0	4
3.	AO7102	Aircraft Structural Mechanics	3	1	0	4
4.	AO7103	Aerospace Propulsion	3	1	0	4
5.	AO7104	Theory of Vibrations	3	0	0	3
6.		Elective I	3	0	0	3
PRACTICAL						
7.	AO7111	Aerodynamics Laboratory	0	0	4	2
		TOTAL	18	4	4	24

SEMESTER II

SL. NO	COURSE CODE	COURSE TITLE	L	T	P	C
THEORY						
1.	AO7201	Flight Mechanics	3	1	0	4
2.	AO7202	Finite Element Methods	3	1	0	4
3.	AO7203	Computational Fluid Dynamics in Aerospace Engineering	3	1	0	4
4.	AO7204	Composite Materials and Structures	3	0	0	3
5.		Elective II	3	0	0	3
6.		Elective III	3	0	0	3
PRACTICAL						
7.	AO7211	Structures Laboratory	0	0	4	2
		TOTAL	18	3	4	23

SEMESTER III

SL. NO	COURSE CODE	COURSE TITLE	L	T	P	C
THEORY						
1.		Elective IV	3	0	0	3
2.		Elective V	3	0	0	3
PRACTICAL						
4.	AO7311	Project Work (Phase I)	0	0	12	6
		TOTAL	6	0	12	12

SEMESTER IV

SL. NO	COURSE CODE	COURSE TITLE	L	T	P	C
PRACTICAL						
1.	AO7411	Project Work (Phase II)	0	0	24	12
		TOTAL	**0**	**0**	**24**	**12**

TOTAL CREDITS TO BE EARNED FOR THE AWARD OF THE DEGREE = 71

LIST OF ELECTIVES FOR M.E. AERONAUTICAL ENGINEERING

SEMESTER I (Elective I)

SL. NO	COURSE CODE	COURSE TITLE	L	T	P	C
1	AO7001	Boundary Layer Theory	3	0	0	3
2	AO7002	Aircraft Design	3	0	0	3
3	AO7003	Industrial Aerodynamics	3	0	0	3
4	AO7004	Helicopter Aerodynamics	3	0	0	3
5	AO7005	Structural Dynamics	3	0	0	3
6	AO7006	Aero Elasticity	3	0	0	3

SEMESTER II (Elective II & III)

SL. NO	COURSE CODE	COURSE TITLE	L	T	P	C
1	AO7007	Theory of Plates and Shells	3	0	0	3
2	AO7008	High Temperature Problems in Structures	3	0	0	3
3	AO7009	Fatigue and Fracture Mechanics	3	0	0	3
4	AO7010	Theory of Elasticity	3	0	0	3
5	AO7011	Hypersonic Aerodynamics	3	0	0	3
6	AO7012	High Temperature Gas Dynamics	3	0	0	3
7	AO7013	Wind Power Engineering	3	0	0	3

SEMESTER III (Elective IV & V)

SL. NO	COURSE CODE	COURSE TITLE	L	T	P	C
1	AO7014	Experimental Stress Analysis	3	0	0	3
2	AO7015	Computational Heat Transfer	3	0	0	3
3	AO7016	Advanced Propulsion Systems	3	0	0	3
4	AO7017	Experimental Aerodynamics	3	0	0	3
5	AO7018	Rocketry and Space Mechanics	3	0	0	3
6	AO7019	High Speed Jet Flows	3	0	0	3
7	AO7020	Combustion in Jet and Rocket Engines	3	0	0	3
8	AO7021	Propeller Aerodynamics	3	0	0	3
9	AO7022	Aerospace Guidance and Control	3	0	0	3

MA7170   **ADVANCED MATHEMATICAL METHODS**   **L T P C**
                                                                  3 1 0 4

OBJECTIVES:
- To familiarize the students in differential equations for solving boundary value problems associated with engineering applications.
- To expose the students to calculus of variation, conformal mappings and tensor analysis.

OUTCOME:
- This subject helps to develop the mathematical methods of applied mathematics and mathematical physics with an emphasis on calculus of variation and integral transforms.

UNIT I   LAPLACE TRANSFORM TECHNIQUES FOR PARTIAL
**   DIFFERENTIAL EQUATIONS   (9+3)**
Laplace transform: Definitions, properties -Transform of 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   (9+3)**
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 Poison's equations.

UNIT III   CALCULUS OF VARIATIONS   (9+3)
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 – problems with constraints - Direct methods: Ritz and Kantorovich methods.

UNIT IV   CONFORMAL MAPPING AND APPLICATIONS   (9+3)
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   (9+3)
Summation convention – Contravariant and covariant vectors – contraction of tensors – innerproduct – quotient law – metric tensor – Christoffel symbols – covariant differentiation – gradient, divergence and curl.

**   TOTAL: 60 PERIODS**

BOOKS FOR STUDY:
1. Sankara Rao K., "Introduction to Partial Differential Equations", Prentice Hall of India Pvt. Ltd., New Delhi,1997.
2. Gupta A.S., "Calculus of Variations with Applications", Prentice Hall of India Pvt. Ltd., New Delhi, 1997.
3. Spiegel M.R., "Theory and Problems of Complex Variables and its Application" (Schaum's Outline Series), McGraw Hill Book Co., Singapore,1981.
4. Ramanaiah, G.T., "Tensor Analysis", S. Viswanatthan Pvt. Ltd., 1990.
5. James G., "Advanced Modern Engineering Mathematics", Pearson Education, Third Edition, 2004.
6. O'Neil P.V., "Advanced Engineering Mathematics", Thomson Asia Pvt. Ltd., Singapore, 2003.

REFERENCES:
1. Andrew L.C. and Shivamoggi B.K., "Integral Transforms for Engineers", Prentice Hall of India Pvt. Ltd., New Delhi, 2003.
2. Elsgolts L., "Differential Equations and the Calculus of Variations", MIR Publishers, Moscow, 1973.
3. Mathews J.H. and Howell R.W., "Complex Analysis for Mathematics and Engineering", Narosa Publishing House, New Delhi,1997.
4. Grewal B.S., "Higher Engineering Mathematics", Khanna Publishers, Fortieth Edition, 2007

AO7101   **AERODYNAMICS**   **L T P C**
                                                                             3 1 0 4

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

UNIT I   INTRODUCTION TO AERODYNAMICS   15
Hot air balloon and aircrafts, Various types of airplanes, Wings and airfoils, lift and Drag, Centre of pressure and aerodynamic centre, Coefficient of pressure, moment coefficient, Continuity and Momentum equations, Point source and sink, doublet, Free and Forced Vortex, Uniform parallel flow, combination of basic flows, Pressure and Velocity distributions on bodies with and without circulation in ideal and real fluid flows, Magnus effect

UNIT II   INCOMPRESSIBLE FLOW THEORY   12
Conformal Transformation, Kutta condition, Karman – Trefftz profiles, Thin aerofoil Theory and its applications. Vortex line, Horse shoe vortex, Biot - Savart law, lifting line theory

UNIT III   COMPRESSIBLE FLOW THEORY   13
Compressibility, Isentropic flow through nozzles, shocks and expansion waves, Rayleigh and Fanno Flow, Potential equation for compressible flow, small perturbation theory, Prandtl- Glauert Rule, Linearised supersonic flow, Method of characteristics

**UNIT IV   AIRFOILS, WINGS AND AIRPLANE CONFIGURATION IN HIGH SPEED
                FLOWS   8**
Critical Mach number, Drag divergence Mach number, Shock stall, super critical airfoils, Transonic area rule, Swept wings (ASW and FSW), supersonic airfoils, wave drag, delta wings, Design considerations for supersonic airplanes

UNIT V   VISCOUS FLOW AND FLOW MEASUREMENTS   12
Basics of viscous flow theory – Boundary Layer – Displacement, momentum and Energy Thickness – Laminar and Turbulent boundary layers – Boundary layer over flat plate – Blasius Solution - Types of wind tunnels – Flow visualization techniques– Measurement of force and moments in wind tunnels.

                                                            TOTAL : 60 PERIODS

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

AO7102   **AIRCRAFT STRUCTURAL MECHANICS**   **L T P C**
                                                                      3 1 0 4

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

UNIT I   BENDING OF BEAMS   12

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

UNIT II   SHEAR FLOW IN OPEN SECTIONS   9

Shear stresses in beams – Shear flow in stiffened panels - Shear flow in thin walled open tubes – Shear centre – Shear flow in open sections with stiffeners.

UNIT III   SHEAR FLOW IN CLOSED SECTIONS   15

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

UNIT IV   STABILITY PROBLEMS   12

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

UNIT V   ANALYSIS OF AIRCRAFT STRUCTURAL COMPONENTS   12

Loads on Wings – Schrenk's curve - Shear force, bending moment and torque distribution along the span of the Wing. Loads on fuselage - Shear and bending moment distribution along the length of the fuselage. Analysis of rings and frames.

TOTAL: 60 PERIODS

REFERENCES

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

AO7103	AEROSPACE PROPULSION	L T P C
		3 1 0 4

OUTCOME:

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

UNIT I   ELEMENTS OF AIRCRAFT PROPULSION   12

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

UNIT II   PROPELLER THEORY   12

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

UNIT III   INLETS, NOZZLES AND COMBUSTION CHAMBERS   12

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

UNIT IV   AXIAL FLOW COMPRESSORS, FANS AND TURBINES   12

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

UNIT V   ROCKET AND ELECTRIC PROPULSION   12

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

TOTAL : 60 PERIODS

REFERENCES

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

AO7104	THEORY OF VIBRATIONS	L T P C
		3 0 0 3

OUTCOME:

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

UNIT I   SINGLE DEGREE OF FREEDOM SYSTEMS   10

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

UNIT II   MULTI-DEGREES OF FREEDOM SYSTEMS   12

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

UNIT III   VIBRATION OF ELASTIC BODIES   10

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

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

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

UNIT V   ELEMENTS OF AEROELASTICITY   5

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

TOTAL : 45 PERIODS

REFERENCES

1. Timoshenko, S. "Vibration Problems in Engineering", John Wiley & Sons, Inc., 1987.

2. Meirovitch, L. "Elements of Vibration Analysis", McGraw-Hill Inc., 1986.
3. Thomson W.T, Marie Dillon Dahleh, "Theory of Vibrations with Applications", Prentice Hall, 1997
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", Wiley Eastern Ltd., New Delhi, 1999.
6. Fung, Y.C., "An Introduction to the Theory of Aeroelasticity", John Wiley & Sons Inc., New York, 1985.

AO7111	**AERODYNAMICS LABORATORY**	**L T P C**
		0 0 4 2

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

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

TOTAL NUMBER OF PERIODS: 60

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

AO7201	**FLIGHT MECHANICS**	**L T P C**
		3 1 0 4

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

UNIT I   PRINCIPLES OF FLIGHT   12
Physical properties and structure of the atmosphere, International Standard Atmosphere, Temperature, pressure and altitude relationship, Measurement of speed – True, Indicated and Equivalent air speed, Streamlined and bluff bodies, Various Types of drag in airplanes, Drag polar, Methods of drag reduction of airplanes.

UNIT II   AIRCRAFT PERFORMANCE IN LEVEL, CLIMBING AND
**   GLIDING FLIGHTS   11**
Straight and level flight, Thrust required and available, Power required and available, Effect of altitude on thrust and power, Conditions for minimum drag and minimum power required, Gliding and Climbing flight, Range and Endurance

UNIT III   ACCELERATED FLIGHT   10

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

UNIT IV   LONGITUDINAL STABILITY AND CONTROL   15

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

UNIT V   LATERAL, DIRECTIONAL STABILITY AND CONTROL   12

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

TOTAL: 60 PERIODS

REFERENCES

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

AO7202   FINITE ELEMENT METHODS   L T P C
**   3 1 0 4**

OUTCOME:

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

UNIT I   INTRODUCTION   12

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

UNIT II   DISCRETE ELEMENTS   14

Structural analysis of bar and beam elements for static and dynamic loadings. Bar of varying section – Temperature effects
Program Development and use of software package for application of bar and beam elements for static, dynamic and stability analysis.

UNIT III   CONTINUUM ELEMENTS   14

Plane stress, Plane strain and Axisymmetric problems – CST Element – LST Element. Consistent and lumped load vectors. Use of local co-ordinates. Numerical integration. Application to heat transfer problems.
Solution for 2-D problems (static analysis and heat transfer) using software packages.

UNIT IV   ISOPARAMETRIC ELEMENTS   12

Definition and use of different forms of 2-D and 3-D elements. - Formulation of element stiffness matrix and load vector.
Solution for 2-D problems (static analysis and heat transfer) using software packages.

UNIT V   SOLUTION SCHEMES   8

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

TOTAL: 60 PERIODS

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

AO7203   **COMPUTATIONAL FLUID DYNAMICS IN AEROSPACE**   **L   T   P   C**
                      ENGINEERING   **3   1   0   4**

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

UNIT I   NUMERICAL SOLUTIONS OF SOME FLUID DYNAMICAL PROBLEMS   15

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

UNIT II   GRID GENERATION   15

Need for grid generation – Various grid generation techniques – Algebraic, conformal and numerical grid generation – importance of grid control functions – boundary point control – orthogonality of grid lines at boundaries.
Elliptic grid generation using Laplace's equations for geometries like airfoil and CD nozzle.

UNIT III   TRANSONIC RELAXATION TECHNIQUES   15

Small perturbation flows, Transonic small perturbation (TSP) equations, Central and backward difference schemes, conservation equations and shockpoint operator, Line relaxation techniques, Acceleration of convergence rate, Jameson's rotated difference scheme -stretching of coordinates, shock fitting techniques Flow in body fitted coordinate system.
Numerical solution of 1-D conduction- convection energy equation using time dependentmethods using both implicit and explicit schemes – application of time split method for the above equation and comparison of the results.

UNIT IV   TIME DEPENDENT METHODS   15

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

UNIT V   PANEL METHODS   15

Elements of two and three dimensional panels, panel singularities. Application of panel methods to incompressible, compressible, subsonic and supersonic flows.

Numerical solution of flow over a cylinder using 2-D panel methods using both vertex and source panel methods for lifting and non lifting cases respectively.

TOTAL: 60 PERIODS

REFERENCES
1. T.J. Chung, Computational Fluid Dynamics, Cambridge University Press, 2002
2. C.Y.Chow, "Introduction to Computational Fluid Dynamics", John Wiley, 1979.
3. A.A. Hirsch, 'Introduction to Computational Fluid Dynamics", McGraw-Hill, 1989.
4. T.K.Bose, "Computation Fluid Dynamics" Wiley Eastern Ltd., 1988.
5. H.J. Wirz and J.J. Smeldern "Numerical Methods in Fluid Dynamics", McGraw-Hill & Co., 1978.
6. John D. Anderson, JR" Computational Fluid Dynamics", McGraw-Hill Book Co., Inc., New York, 1995.

AO7204	COMPOSITE MATERIALS AND STRUCTURES	L T P C
		3 0 0 3

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

UNIT I   INTRODUCTION   10
Classification and characteristics of composite materials - Types of fiber and resin materials, functions and their properties – Application of composite to aircraft structures-Micromechanics-Mechanics of materials, Elasticity approaches-Mass and volume fraction of fibers and resins-Effect of voids, Effect of temperature and moisture.

UNIT II   MACROMECHANICS   10
Hooke's law for orthotropic and anisotropic materials-Lamina stress-strain relations referred to natural axes and arbitrary axes.

UNIT III   ANALYSIS OF LAMINATED COMPOSITES   10
Governing equations for anisotropic and orthotropic plates- Angle-ply and cross ply laminates-Analysis for simpler cases of composite plates and beams - Interlaminar stresses.

UNIT IV   MANUFACTURING & FABRICATION PROCESSES   8
Manufacture of glass, boron and carbon fibers-Manufacture of FRP components- Open mould and closed mould processes. Properties and functions of resins.

UNIT V   OTHER METHODS OF ANALYSIS AND FAILURE THEORY   7
Netting analysis- Failure criteria-Flexural rigidity of Sandwich beams and plates – composite repair- AE technique.

TOTAL: 45 PERIODS

REFERENCES
1. R.M. Jones, "Mechanics of Composite Materials", 2nd Edition, Taylor & Francis, 1999
2. L.R. Calcote, "Analysis of laminated structures", Van Nostrand Reinhold Co.,1989.
3 Autar K. Kaw, Mechanics of Composite Materials, CRC Press LLC, 1997
4. G.Lubin, "Hand Book on Fibre glass and advanced plastic composites", Van Nostrand Co., New York, 1989.
5. B.D. Agarwal and L.J. Broutman, "Analysis and Performance of fiber composites", John-Wiley and Sons, 1990.

AO7211   **STRUCTURES LABORATORY**   **L T P C**
                                                                          0 0 4 2

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

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

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

                                                        TOTAL: 60 PERIODS

LABORATORY EQUIPMENTS REQUIREMENTS
1. Constant strength beam setup
2. Column setup
3. Unsymmetrical Bending setup
4. Experimental setup for location of shear centre (open & close section)
5. Cantilever beam setup
6. Experimental setup for bending and torsional loads
7. Diffuser transmission type polariscope with accessories
8. Experimental setup for vibration of beams
9. Universal Testing Machine
10. Wagner beam setup

AO7001   **BOUNDARY LAYER THEORY**   **L T P C**
                                                                          3 0 0 3

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

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

UNIT II   LAMINAR BOUNDARY LAYER   9
Development of boundary layer – Estimation of boundary layer thickness, Displacement thickness - Momentum and energy thicknesses for two dimensional flow – Two dimensional boundary layer equations – Similarity solutions - Blasius solution.

UNIT III   TURBULENT BOUNDARY LAYER   9
Physical and mathematical description of turbulence, two-dimensional turbulent boundary layer equations, Velocity profiles – Inner, outer and overlap layers, Transition from laminar to turbulent boundary layers, turbulent boundary layer on a flat plate, mixing length hypothesis.

UNIT IV   APPROXIMATE SOLUTION TO BOUNDARY LAYER EQUATIONS   9
Approximate integral methods, digital computer solutions – Von Karman – Polhausen method.

UNIT V   THERMAL BOUNDARY LAYER   9
Introduction to thermal boundary layer – Heat transfer in boundary layer - Convective heat transfer, importance of non dimensional numbers – Prandtl number, Nusselt number, Lewis number etc.

TOTAL: 45 PERIODS

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

AO7002   AIRCRAFT DESIGN   L T P C
3 0 0 3

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

UNIT I   REVIEW OF DEVELOPMENTS IN AVIATION   9
Categories and types of aircrafts – various configurations – Layouts and their relative merits – strength, stiffness, fail safe and fatigue requirements – Manoeuvering load factors – Gust and manoeuverability envelopes – Balancing and maneuvering loads on tail planes.

UNIT II   POWER PLANT TYPES AND CHARACTERISTICS   9
Characteristics of different types of power plants – Propeller characteristics and selection – Relative merits of location of power plant.

UNIT III   PRELIMINARY DESIGN   9
Selection of geometric and aerodynamic parameters – Weight estimation and balance diagram – Drag estimation of complete aircraft – Level flight, climb, takeoff and landing calculations – range and endurance – static and dynamic stability estimates – control requirements.

UNIT IV   SPECIAL PROBLEMS   9
Layout peculiarities of subsonic and supersonic aircraft – optimization of wing loading to achieve desired performance – loads on undercarriages and design requirements.

UNIT V   STRUCTURAL DESIGN   9
Estimation of loads on complete aircraft and components – Structural design of fuselage, wings and undercarriages, controls, connections and joints. Materials for modern aircraft – Methods of analysis, testing and fabrication.

PRACTICALS
Conceptual design of an aircraft for given specifications.

TOTAL: 45 PERIODS

REFERENCES
1. D.P. Raymer, "Aircraft conceptual design", AIAA Series, 1988.
2. G. Corning, "Supersonic & Subsonic Airplane Design", II Edition, Edwards Brothers Inc., Michigan, 1953.
3. E.F. Bruhn, "Analysis and Design of Flight Vehicle Structures", Tristate Offset Co., U.S.A., 1980.
4. E. Torenbeek, "Synthesis of Subsonic Airplane Design", Delft University Press, London, 1976.

5. H.N.Kota, Integrated design approach to Design fly by wire" Lecture notes Interline Pub. Bangalore, 1992.
6. A.A. Lebedenski, "Notes on airplane design", Part-I, I.I.Sc., Bangalore, 1971.

AO7003	INDUSTRIAL AERODYNAMICS	L T P C
		3 0 0 3

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

UNIT I   ATMOSPHERE   9
Types of winds, Causes of variation of winds, Atmospheric boundary layer, Effect of terrain on gradient height, Structure of turbulent flows.

UNIT II   WIND ENERGY COLLECTORS   9
Horizontal axis and vertical axis machines, Power coefficient, Betz coefficient by momentum theory.

UNIT III   VEHICLE AERODYNAMICS   9
Power requirements and drag coefficients of automobiles, Effects of cut back angle, Aerodynamics of trains and Hovercraft.

UNIT IV   BUILDING AERODYNAMICS   9
Pressure distribution on low rise buildings, wind forces on buildings. Environmental winds in city blocks, Special problems of tall buildings, Building codes, Building ventilation and architectural aerodynamics.

UNIT V   FLOW INDUCED VIBRATIONS   9
Effects of Reynolds number on wake formation of bluff shapes, Vortex induced vibrations, Galloping and stall flutter.

TOTAL: 45 PERIODS

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

AO7004	HELICOPTER AERODYNAMICS	L T P C
		3 0 0 3

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

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

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

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

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

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

TOTAL: 45 PERIODS

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

AO7005   STRUCTURAL DYNAMICS   L T P C
                                                                        3 0 0 3

OUTCOME:
Upon completion of the course, students will learn how to use the approximate methods for dynamic response of continuous systems.

UNIT I   FORCE-DEFLECTION PROPERTIES OF STRUCTURES   10
Constraints and Generalized coordinates – Virtual work and generalized forces – Force – Deflection influence functions – stiffness and flexibility methods.

UNIT II   PRINCIPLES OF DYNAMICS   10
Free, Damped and forced vibrations of systems with finite degrees of freedom. D"Alembert's principle – Hamilton's principle – Lagrange's equations of motion and its applications.

UNIT III   NATURAL MODES OF VIBRATION   10
Equations of motion for free vibrations. Solution of Eigen value problems – Normal coordinates and orthogonality conditions of eigen vectors.

UNIT IV   ENERGY METHODS   8
Rayleigh's principle and Rayleigh – Ritz method. Coupled natural modes. Effect of rotary inertia and shear on lateral vibrations of beams.

UNIT V   APPROXIMATE METHODS   7
Approximate methods of evaluating the eigen values and the dynamic response of continuous systems. Application of Matrix methods for dynamic analysis.

TOTAL: 45 PERIODS

REFERENCES
1. W.C. Hurty and M.F. Rubinstein, "Dynamics of Structures", Prentice Hall of India Pvt., Ltd., New Delhi, 1987.
2. F.S.Tse, I.E. Morse and H.T. Hinkle, "Mechanical Vibration", Prentice Hall of India Pvt., Ltd., New Delhi, 1988.
3. R.K. Vierck, "Vibration Analysis", 2nd Edition, Thomas Y. Crowell & Co., Harper & Row Publishers, New York, U.S.A., 1989.

4. S.P. Timoshenko and D.H. Young, "Vibration Problems in Engineering", John Willey & Sons Inc., 1984.
5. Von. Karman and A.Biot, "Mathematical Methods in Engineering", McGraw-Hill Book Co., New York, 1985.

AO7006   **AEROELASTICITY**   **L T P C**
                                                                       3 0 0 3

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

UNIT I   AEROELASTIC PHENOMENA   6
Stability versus response problems – The aero-elastic triangle of forces – Aeroelasticity in Aircraft Design – Prevention of aeroelastic instabilities. Influence and stiffness co-efficients. Flexure – torsional oscillations of beam – Differential equation of motion of beam.

UNIT II   DIVERGENCE OF A LIFTING SURFACE   10
Simple two dimensional idealisations-Strip theory – Integral equation of the second kind – Exact solutions for simple rectangular wings – 'Semirigid' assumption and approximate solutions – Generalised coordinates – Successive approximations – Numerical approximations using matrix equations.

UNIT III   STEADY STATE AEROLASTIC PROBLEMS   9
Loss and reversal of aileron control – Critical aileron reversal speed – Aileron efficiency – Semi rigid theory and successive approximations – Lift distribution – Rigid and elastic wings. Tail efficiency. Effect of elastic deformation on static longitudinal stability.

UNIT IV   FLUTTER PHENOMENON   14
Non-dimensional parameters – Stiffness criteria – Dynamic mass balancing – Dimensional similarity. Flutter analysis – Two dimensional thin airfoils in steady incompressible flow – Quasisteady aerodynamic derivatives. Galerkin method for critical flutter speed – Stability of disturbed motion – Solution of the flutter determinant – Methods of determining the critical flutter speeds – Flutter prevention and control.

UNIT V   EXAMPLES OF AEROELASTIC PROBLEMS   6
Galloping of transmission lines and Flow induced vibrations of transmission lines, tall slender structures and suspension bridges, VIV.

                                                           TOTAL: 45 PERIODS

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

AO7007   **THEORY OF PLATES AND SHELLS**   **L T P C**
                                                                                  3 0 0 3

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

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

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

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

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

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

                                                         TOTAL: 45 PERIODS
REFERENCES
1. Timoshenko, S.P. Winowsky. S., and Kreger, Theory of Plates and Shells, McGraw Hill Book Co., 1990.
2. T.K.Varadan & K. Bhaskar, "Análysis of plates – Theory and problems", Narosha Publishing Co., 1999.
3. Flugge, W. Stresses in Shells, Springer – Verlag, 1985.
4. Timoshenko, S.P. and Gere, J.M., Theory of Elastic Stability, McGraw Hill Book Co. 1986.
5. Harry Kraus, 'Thin Elastic Shells', John Wiley and Sons, 1987.

AO7008   **HIGH TEMPERATURE PROBLEMS IN STRUCTURES**   **L T P C**
                                                                          3 0 0 3

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

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

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

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

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

UNIT V   SPECIAL TOPICS & MATERIALS   9
Thermal bucking – Analysis including material properties variation with temperature..

TOTAL: 45 PERIODS

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

AO7009   **FATIGUE AND FRACTURE MECHANICS**   **L T P C**
                                                              3 0 0 3

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

UNIT I   FATIGUE OF STRUCTURES   10
S.N. curves – Endurance limit – Effect of mean stress – Goodman, Gerber and Soderberg relations and diagrams – Notches and stress concentrations – Neuber's stress concentration factors – plastic stress concentration factors – Notched S-N curves.

UNIT II   STATISTICAL ASPECTS OF FATIGUE BEHAVIOUR   8
Low cycle and high cycle fatigue – Coffin-Manson's relation – Transition life – Cyclic Strain hardening and softening – Analysis of load histories – Cycle counting techniques – Cumulative damage – Miner's theory – other theories.

UNIT III   PHYSICAL ASPECTS OF FATIGUE   5
Phase in fatigue life – Crack initiation – Crack growth – Final fracture – Dislocations – Fatigue fracture surfaces.

UNIT IV   FRACTURE MECHANICS   15
Strength of cracked bodies – potential energy and surface energy – Griffith's theory – Irwin – Orwin extension of Griffith's theory to ductile materials – Stress analysis of cracked bodies – Effect of thickness on fracture toughness – Stress intensity factors for typical geometries.

UNIT V   FATIGUE DESIGN AND TESTING   7
Safe life and fail safe design philosophies – Importance of Fracture Mechanics in aerospace structure – Application to composite materials and structures.

TOTAL: 45 PERIODS

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

AO7010   **THEORY OF ELASTICITY**   **L T P C**
                                                                          3 0 0 3

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

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

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

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

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

UNIT V   TORSION   8
Coulomb's theory-Navier's theory-Saint Venant's Semi-Inverse method – Torsion of Circular, Elliptical and Triangular sections - Prandtl's theory-Membrane analogy.
                                                          TOTAL: 45 PERIODS

REFERENCES
1. Ugural, A.C and Fenster, S.K, Advanced Strength and Applied Elasticity, Prentice hall, 2003
2. Wang, C.T. Applied elasticity, McGraw Hill 1993
3. Enrico Volterra and Caines, J.H, Advanced strength of Materials, Prentice Hall,1991.
4. S.P. Timoshenko and J.N. Goodier, Theory of Elasticity, McGraw-Hill, 1985.
5. E. Sechler, "Elasticity in Engineering" John Wiley & Sons Inc., New York, 1980.

AO7011   **HYPERSONIC AERODYNAMICS**   **L T P C**
                                                                          3 0 0 3

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

UNIT I   BASICS OF HYPERSONIC AERODYNAMICS   8
Thin shock layers – entropy layers – low density and high density flows – hypersonic flight paths hypersonic flight similarity parameters – shock wave and expansion wave relations of inviscid hypersonic flows.

UNIT II   SURFACE INCLINATION METHODS FOR HYPERSONIC INVISCID FLOWS   9
Local surface inclination methods – modified Newtonian Law – Newtonian theory – tangent wedge or tangent cone and shock expansion methods – Calculation of surface flow properties

UNIT III **APPROXIMATE METHODS FOR INVISCID HYPERSONIC FLOWS'** **9**

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

UNIT IV **VISCOUS HYPERSONIC FLOW THEORY** **10**

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

UNIT V **VISCOUS INTERACTIONS IN HYPERSONIC FLOWS** **9**

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

TOTAL: 45 PERIODS

REFERENCES

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

AO7012 **HIGH TEMPERATURE GAS DYNAMICS** **L T P C**
3 0 0 3

OUTCOME:

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

UNIT I **INTRODUCTION** **8**

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

UNIT II **STATISTICAL THERMODYNAMICS** **8**

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

UNIT III **KINETIC THEORY AND HYPERSONIC FLOWS** **9**

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

UNIT IV **INVISCID HIGH TEMPERATURE FLOWS** **10**

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

UNIT V **TRANSPORT PROPERTIES IN HIGH TEMPERATURE GASES** **10**

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

TOTAL: 45 PERIODS

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

AO7013	**WIND POWER ENGINEERING**	L T P C
		3 0 0 3

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

UNIT I   INTRODUCTION TO WIND ENERGY   8
Background,Motivations, and Constraints, Historical perspective, Modern wind turbines, Components and geometry, Power characteristics.

UNIT II   WIND CHARACTERISTICS AND RESOURCES   8
General characteristics of the wind resource, Atmospheric boundarylayer characteristics, Wind data analysis and resource estimation, Wind turbine energy production estimates using statistical techniques

UNIT III   AERODYNAMICS OF WIND TURBINES   12
Overview , 1-D Momentum theory,Ideal horizontal axis wind turbine with wake rotation, Airfoils and aerodynamic concepts -Momentum theory and blade element theory General rotor blade shape performance prediction - Wind turbine rotor dynamics

UNIT IV   WIND TURBINE DESIGN& CONTROL   9
Brief design overview – Introduction -Wind turbine control systems -Typical grid-connected turbine operation -Basic concepts of electricpower- Power transformers -Electrical machines

UNIT V   ENVIRONMENTAL AND SITE ASPECTS   8
Overview- Wind turbine siting - Installation and operation- Wind farms- Overview of wind energy economics-Electromagnetic interference-noise-Land use impacts - Safety

TOTAL: 45 PERIODS

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

AO7014   **EXPERIMENTAL STRESS ANALYSIS**   **L T P C**
                                                                3 0 0 3

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

UNIT I   **INTRODUCTION**   **8**
Principle of measurements-Accuracy, sensitivity and range- Mechanical, Optical, Acoustical and Electrical extensometers.

UNIT II   **ELECTRICAL RESISTANCE STRAIN GAUGES**   **12**
Principle of operation and requirements-Types and their uses-Materials for strain gauge-Calibration and temperature compensation-Cross sensitivity-Rosette analysis-Wheatstone bridge-Potentiometer circuits for static and dynamic strain measurements-Strain indicators- Application of strain gauges to wind tunnel balance.

UNIT III   **PRINCIPLES OF PHOTOELASTICITY**   **9**
Two dimensional photo elasticity-Concepts of photoelastic effects-Photoelastic materials-Stress optic law-Plane polariscope–Circular polariscope-Transmission and Reflection type-Effect of stressed model in Plane and Circular polariscope. Interpretation of fringe pattern Isoclinics and Isochromatics.-Fringe sharpening and Fringe multiplication techniques-Compensation and separation techniques-Introduction to three dimensional photoelasticity.

UNIT IV   **PHOTOELASTICITY AND INTERFEROMETRY TECHNIQUES**   **9**
Fringe sharpening and Fringe multiplication techniques-Compensation and separation techniques-Calibration methods –Photo elastic materials. Introduction to three dimensional photoelasticity. Moire fringes – Laser holography – Grid methods-Stress coat

UNIT V   **NON DESTRUCTIVE TECHNIQUES**   **7**
Radiography- Ultrasonics- Magnetic particle inspection- Fluorescent penetrant technique-Eddy current testing– thermography– MICRO FOCUS CT scan.

                                                      TOTAL: 45 PERIODS

REFERENCES
1. J.W. Dally and M.F. Riley, "Experimental Stress Analysis", McGraw-Hill Book Co., New York, 1988.
2. Srinath,L.S., Raghava,M.R., Lingaiah,K. Gargesha,G.,Pant B. and Ramachandra,K. – Experimental Stress Analysis, Tata McGraw Hill, New Delhi, 1984
3. P. Fordham, "Non-Destructive Testing Techniques" Business Publications, London, 1988.
4. M. Hetenyi, "Handbook of Experimental Stress Analysis", John Wiley & Sons Inc., New York, 1980.
5. G.S. Holister, "Experimental Stress Analysis, Principles and Methods", Cambridge University Press, 1987.
6. A.J. Durelli and V.J. Parks, "Moire Analysis of Strain", Prentice Hall Inc., Englewood Cliffs, New Jersey, 1980.

AO7015   **COMPUTATIONAL HEAT TRANSFER**   **L T P C**
                                                                 3 0 0 3

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

UNIT I   **INTRODUCTION**   **9**
Finite Difference Method-Introduction-Taylor's series expansion - Discretisation Methods Forward, backward and central differencing scheme for I^{st} 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

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

AO7016	ADVANCED PROPULSION SYSTEMS	L T P C
		3 0 0 3

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

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

UNIT II   RAMJETS AND AIR AUGMENTED ROCKETS   8

Preliminary performance calculations – Diffuser design with and without spike, Supersonic inlets – combustor and nozzle design – integral Ram rocket.

UNIT III   SCRAMJET PROPULSION SYSTEM   12

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

UNIT IV   NUCLEAR PROPULSION   9

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

UNIT V   ELECTRIC AND ION PROPULSION   8

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

TOTAL: 45 PERIODS

REFERENCES

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

AO7017   **EXPERIMENTAL AERODYNAMICS**   **L T P C**
                                                                                                    3 0 0 3

OUTCOME:

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

UNIT I   BASIC MEASUREMENTS IN FLUID MECHANICS   8

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

UNIT II   WIND TUNNEL MEASEUREMENTS   8

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

UNIT III   FLOW VISUALIZATION AND ANALOGUE METHODS   10

Visualization techniques – Smoke tunnel – Hele-Shaw apparatus - Interferometer – Fringe-Displacement method – Shadowgraph - Schlieren system – Background Oriented Schliren (BOS) System - Hydraulic analogy – Hydraulic jumps – Electrolytic tank

UNIT IV PRESSURE, VELOCITY AND TEMPERATURE MEASUREMENTS 10

Pitot-Static tube characteristics - Velocity measurements - Hot-wire anemometry – Constant current and Constant temperature Hot-Wire anemometer – Hot-film anemometry – Laser Doppler Velocimetry (LDV) – Particle Image Velocimetry (PIV) – Pressure Sensitive Paints - Pressure measurement techniques - Pressure transducers – Temperature measurements.

UNIT V DATA ACQUISITION SYSTEMS AND UNCERTAINTY ANALYSIS 9

Data acquisition and processing – Signal conditioning - Estimation of measurement errors – Uncertainty calculation - Uses of uncertainty analysis.

TOTAL: 45 PERIODS

REFERENCES

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

AO7018 **MECHANICS** **L T P C**

3 0 0 3

OUTCOME:

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

UNIT I ORBITAL MECHANICS 9

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

UNIT II SATELLITE DYNAMICS 9

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

UNIT III ROCKET MOTION 10

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

UNIT IV ROCKET AERODYNAMICS 9

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

UNIT V STAGING AND CONTROL OF ROCKET VEHICLES 8

Need for multistaging of rocket vehicles – multistage vehicle optimization – stage separation dynamics and separation techniques- aerodynamic and jet control methods of rocket vehicles - SITVC.

TOTAL: 45 PERIODS

REFERENCES

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

AO7019 **HIGH SPEED JET FLOWS** **L T P C**
                                                    3 0 0 3

OUTCOME:
Upon completion of the course, students will learn the basics of nozzle flows, methods of jet control and acoustics of jet.

UNIT I   INTRODUCTION   9
Types of nozzles – overexpanded and underexpanded flows - Isentropic flow through nozzles– Interaction of nozzle flows over adjacent surfaces – Mach disk - Jet flow – types - Numerical problems.

UNIT II   COMPRESSIBLE FLOW THEORY   9
One-dimensional compressible fluid flow – flow through variable area passage – nozzles and diffusers –normal and oblique shock waves and calculation of flow and fluid properties across the shocks and expansion fans. Interaction of shocks with solid and fluid surface.

UNIT III   JET CONTROL   9
Types of jet control - single jet, multi jet, co-flow jet, parallel flow jet. Subsonic jets- Mathematical treatment of jet profiles- Theory of Turbulent jets- Mean velocity and mean temperature- Turbulence characteristics of free jets- Mixing length- Experimental methods for studying jets and the Techniques used for analysis- Expansion levels of jets- Overexpanded, Correctly expanded, Underexpanded jets - Control of jets. Centre line decay, Mach number Profile, Iso-Mach (or iso-baric) contours, Shock cell structure in underexpanded and overexpanded jets, Mach discs.

UNIT IV   BOUNDARY LAYER CONCEPT   9
Boundary Layer – displacement and momentum thickness- laminar and turbulent boundary layers over flat plates – velocity distribution in turbulent flows over smooth and rough boundaries- laminar sublayer. Shock-boundary layer interactions.

UNIT V   JET ACOUSTICS   9
Introduction to Acoustic – Types of noise – Source of generation- Traveling wave solution- standing wave solution – multi-dimensional acoustics -Noise suppression techniques– applications to problems.

                                                            TOTAL: 45 PERIODS
REFERENCES
1.   Ethirajan Rathakrishnan, "Applied Gas Dynamics", John Wiley, NY,, 2010.
2. Shapiro, AH, "Dynamics and Thermodynamics of Compressible Fluid Flow", Vols. I &   II, Ronald Press, New York, 1953.
3. Rathakrishnan E**.,** "Gas Dynamics"**,** Prentice Hall of India, New Delhi, 2008.
4. Liepmann and Roshko, "Elements of Gas Dynamics", John Wiley, NY, 1963.

AO7020 **COMBUSTION IN JET AND ROCKET ENGINES** **L T P C**
                                                    3 0 0 3

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

UNIT I   THERMODYNAMICS OF COMBUSTION   8
Staichiometry – absolute enthalpy- enthalpy of formation- enthalpy of combustion- laws of thermochemistry- pressure and temperature effect on enthalpy of formation, adiabatic flame temperature, chemical and equillibrium products of combustion.

UNIT II   PHYSICS AND CHEMISTRY OF COMBUSTION   9

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

UNIT III   PREMIXED AND DIFFUSED FLAMES   12

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

UNIT IV   COMBUSTION IN GAS TURBINE , RAMJET AND SCRAMJET   8

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

UNIT V   COMBUSTION IN CHEMICAL ROCKET   8

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

TOTAL: 45 PERIODS

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

AO7021   PROPELLER AERODYNAMICS   L T P C
3 0 0 3

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

UNIT I   AIR SCREW THEORY   8

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

UNIT II   THE AXIAL MOMENTUM THEORY   10

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

UNIT III   THE BLADE ELEMENT THEORY   9

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

UNIT IV   THE VORTEX THEORY   9

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

UNIT V   EXPERIMENTAL AND SIMULATION APPROACH OF PROPELLERS   9

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

TOTAL: 45 PERIODS

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

AO7022   AEROSPACE GUIDANCE AND CONTROL   L T P C
3 0 0 3

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

UNIT I   INTRODUCTION   4
Introduction to Guidance and control - definition, Historical background

UNIT II   AUGMENTATION SYSTEMS   7
Need for automatic flight control systems, Stability augmentation systems, control augmentation systems, Gain scheduling concepts.

UNIT III   LONGITUDINAL AUTOPILOT   12
Displacement Autopilot-Pitch Orientation Control system, Acceleration Control System, Glide Slope Coupler and Automatic Flare Control and Flight path stabilization, Longitudinal control law design using back stepping algorithm.

UNIT IV   LATERAL AUTOPILOT   10
Damping of the Dutch Roll, Methods of Obtaining Coordination, Yaw Orientation Control system, turn compensation, Automatic lateral Beam Guidance. Introduction to Fly-by-wire flight control systems, Lateral control law design using back stepping algorithm.

UNIT V   MISSILE AND LAUNCH VEHICLE GUIDANCE   12
Operating principles and design of guidance laws, homing guidance laws- short range, Medium range and BVR missiles, Launch Vehicle- Introduction, Mission requirements, Implicit guidance schemes, Explicit guidance, Q guidance schemes

TOTAL: 45 PERIODS

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