

UNIVERSITY DEPARTMENTS  
 ANNA UNIVERSITY CHENNAI :: CHENNAI 600 025  
 REGULATIONS - 2009  
 CURRICULUM I TO IV SEMESTERS (FULL TIME)  
 M.E. AERONAUTICAL ENGINEERING

**SEMESTER I**

SL.No.	COURSE CODE	COURSE TITLE	L	T	P	C
<b>THEORY</b>						
1	MA9115	<a href="#">Applied Mathematics</a>	3	1	0	4
2	AE9111	<a href="#">Aerodynamics</a>	3	1	0	4
3	AE9112	<a href="#">Aircraft Structures</a>	3	1	0	4
4	AE9113	<a href="#">Aerospace Propulsion</a>	3	1	0	4
5	AE9114	<a href="#">Theory of Vibrations</a>	3	0	0	3
6	E1	Elective II	3	0	0	3
<b>PRACTICAL</b>						
7	AE9115	<a href="#">Structures Laboratory</a>	0	0	4	2
<b>TOTAL</b>			<b>18</b>	<b>4</b>	<b>4</b>	<b>22</b>

**SEMESTER II**

SL.No.	COURSE CODE	COURSE TITLE	L	T	P	C
<b>THEORY</b>						
1	AE9121	<a href="#">Flight Mechanics</a>	3	0	0	3
2	AE9122	<a href="#">Finite Element Methods*</a>	3	0	2	4
3	AE9123	<a href="#">Computational Fluid Dynamics in Aerospace Engineering</a>	3	0	2	4
4	E2	Elective II	3	0	0	3
5	E3	Elective III	3	0	0	3
6	E4	Elective IV	3	0	0	3
<b>PRACTICAL</b>						
7	AE9124	<a href="#">Aerodynamics Laboratory</a>	0	0	4	2
<b>TOTAL</b>			<b>18</b>	<b>0</b>	<b>8</b>	<b>22</b>

### SEMESTER III

SL.No.	COURSE CODE	COURSE TITLE	L	T	P	C
<b>THEORY</b>						
1	E5	Elective V	3	0	0	3
2	E6	Elective VI	3	0	0	3
<b>PRACTICAL</b>						
3	AE9131	Project work Phase I	0	0	12	6
<b>TOTAL</b>			<b>6</b>	<b>0</b>	<b>12</b>	<b>12</b>

### SEMESTER IV

SL.No.	COURSE CODE	COURSE TITLE	L	T	P	C
<b>PRACTICAL</b>						
1	AE9141	Project work Phase II	0	0	24	12
<b>TOTAL</b>			<b>0</b>	<b>0</b>	<b>24</b>	<b>12</b>

\* Term paper

$$\text{TOTAL} = 24 + 22 + 12 + 12 = 70$$

### LIST OF ELECTIVES

S.NO	COURSE CODE	COURSE TITLE	L	T	P	C
1.	AE9150	<a href="#">Experimental Stress Analysis</a>	3	0	0	3
2.	AE9151	<a href="#">Numerical Heat Transfer</a>	2	0	2	3
3.	AE9152	<a href="#">Boundary Layer Theory</a>	3	0	0	3
4.	AE9153	<a href="#">Aircraft Design</a>	2	0	2	3
5.	AE9154	<a href="#">Industrial Aerodynamics</a>	3	0	0	3
6.	AE9155	<a href="#">Helicopter Aerodynamics</a>	3	0	0	3
7.	AE9156	<a href="#">Theory of Plates and Shells</a>	3	0	0	3
8.	AE9157	<a href="#">Structural Dynamics</a>	3	0	0	3
9.	AE9158	<a href="#">Aero elasticity</a>	3	0	0	3
10.	AE9159	<a href="#">High Temperature Problems in Structures</a>	3	0	0	3
11.	AE9160	<a href="#">Fatigue and Fracture Mechanics</a>	3	0	0	3
12.	AE9161	<a href="#">Theory of Elasticity</a>	3	0	0	3
13.	AE9162	<a href="#">Hypersonic Aerodynamics</a>	3	0	0	3
14.	AE9163	<a href="#">High Temperature Gas Dynamics</a>	3	0	0	3
15.	AE9164	<a href="#">Advanced Propulsion Systems</a>	3	0	0	3
16.	AE9165	<a href="#">Experimental Methods in Fluid Mechanics</a>	3	0	0	3
17.	AE9166	<a href="#">Wind Engineering</a>	3	0	0	3
18.	AE9167	<a href="#">Wind Tunnel Techniques</a>	3	0	0	3
19.	AE9168	<a href="#">Rocketry and Space Mechanics</a>	3	0	0	3
20.	AE9169	<a href="#">Composite Materials and Structures</a>	3	0	0	3



## REFERENCES

1. Froberg, C.E. Numerical Mathematics, The Benjamin/Cummings Publishing Co., Inc., 1985.
2. Jain, M.K., Iyengar, S.R.K., and Jain, R.K., Numerical Methods for Scientific & Engineering computation, Wiley Eastern Ltd., 1987.
3. Gupta, A.S. Calculus of Variations with Applications, Prentice Hall of India Pvt. Ltd., New Delhi, 1997.
4. Sankara Rao, K., Introduction to Partial Differential Equations, Prentice Hall of India Pvt Ltd., New Delhi 1997.
5. Boyce & DiPrima, Elementary Differential Equations and Boundary value problems, with ODE Architect CD, 8<sup>th</sup> Edition, 2005.

**OBJECTIVE**

To 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 processes – Measurement of force and moments in wind tunnels.

**L : 45 T : 15 - TOTAL NUMBER OF PERIODS : 60**

**TEXT BOOKS**

1. J.D. Anderson, "Fundamentals of Aerodynamics", McGraw-Hill Book Co., New York, 1985.
2. Rathakrishnan.E., Gas Dynamics, Prentice Hall of India, 1995.

**REFERENCES**

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

**OBJECTIVE**

To study 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 - Bredt-Batho theory - 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 - 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.

**L : 45, T : 15, TOTAL NUMBER OF PERIODS: 60**

**TEXT BOOKS**

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.

**REFERENCES**

1. Peery, D.J. and Azar, J.J., Aircraft Structures, 2<sup>nd</sup> Edition, McGraw-Hill, New York, 1993.
2. Stephen P. Timoshenko & S.woinowsky Krieger, Theory of Plates and Shells, 2<sup>nd</sup> Edition, McGraw-Hill, Singapore, 1990.
3. Rivello, R.M., Theory and Analysis of Flight structures, McGraw-Hill, N.Y., 1993



**OBJECTIVE**

To study the dynamic behaviour of different aircraft components and the interaction among the aerodynamic, elastic and inertia forces

**UNIT I SINGLE DEGREE OF FREEDOM SYSTEMS 8**

Simple harmonic motion, definition of terminologies, Newton's Laws, D'Alembert's principle, Energy methods. Free vibrations, free damped vibrations, 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, Lagrangean equation and their 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 10**

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.

**L : 45, TOTAL NUMBER OF PERIODS: 45**

**TEXT BOOKS**

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

**REFERENCES**

1. F.S. Tse., I.F. Morse and R.T. Hinkle, "Mechanical Vibrations", Prentice-Hall of India, 1985.
2. Rao.J.S. and Gupta.K. "Theory and Practice of Mechanical Vibrations", Wiley Eastern Ltd., New Delhi, 1999.
3. Fung, Y.C., "An Introduction to the Theory of Aeroelasticity", John Wiley & Sons Inc., New York, 1985.



**OBJECTIVE**

To experimentally study the unsymmetrical bending of beams, find the location of shear centre, obtain the stresses in circular discs and beams using photoelastic techniques, calibration of photo – elastic materials and study on vibration of beams.

**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

**TOTAL NUMBER OF PERIODS: 60**

**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

**OBJECTIVE**

To understand the behaviour of airflow over bodies with particular emphasis on airfoil sections in the incompressible flow regime.

**UNIT I PRINCIPLES OF FLIGHT 7**

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 FLIGHT 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 ACCELERATING FLIGHT 8**

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

**UNIT IV LONGITUDINAL STABILITY AND CONTROL 10**

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

**UNIT V LATERAL, DIRECTIONAL STABILITY AND CONTROL 9**

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

**L : 45, TOTAL NUMBER OF PERIODS: 45**

**TEXT BOOKS**

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.

**REFERENCES**

1. Kuethe, A.M., and Chow, C.Y., Foundations of Aerodynamics, John Wiley & Sons, 1982.
2. Clancey, L.J. Aerodynamics, Pitman, 1986.
3. Babister, A.W. Aircraft stability and response, Pergamon Press, 1980.
4. Nelson, R.C. Flight Stability & Automatic Control, McGraw-Hill, 1989.
5. McCormic, B.W., Aerodynamics, Aeronautics & Flight Mechanics John Wiley, 1995.

**OBJECTIVE**

To introduce the concept of numerical analysis of structural components

**UNIT I INTRODUCTION 10**

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 10**

Use of bar and beam elements for static, dynamic and structural analysis – Bar of varying section – Temperature effects

**Practical**

Program Development and use of software package for application of bar and beam elements for static, dynamic and stability analysis. **10**

**UNIT III CONTINUUM ELEMENTS 12**

Different forms of 2-D elements and their applications for plane stress, plane strain and axisymmetric problems – CST Element – LST Element - Consistent and lumped load vectors. Use of local co-ordinates. Numerical integration. – 2-D formulations for scalar variable problems - Application to heat transfer problems.

**Practical**

Solution for 2-D problems (static analysis and heat transfer) using software packages. **10**

**UNIT IV ISOPARAMETRIC ELEMENTS 8**

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

**Practical**

Solution for 2-D problems (static analysis and heat transfer) using software packages. **10**

**UNIT V SOLUTION SCHEMES 5**

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

**L : 45, P:30 TOTAL NUMBER OF PERIODS: 75**

**TEXT BOOKS**

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, 3<sup>rd</sup> Edition, 1998

**REFERENCES**

1. Robert D. Cook, David S. Malkus, Michael E. Plesha and Robert J. Witt "Concepts and Applications of Finite Element Analysis", 4<sup>th</sup> Edition, John Wiley & Sons, 2002.
2. K.J. Bathe and E.L. Wilson, "Numerical Methods in Finite Elements Analysis", Prentice Hall of India Ltd., 1983.
3. C.S. Krishnamurthy, "Finite Elements Analysis", Tata McGraw-Hill, 1987.

**OBJECTIVE**

To study the flow of dynamic fluids by computational methods

**UNIT I                  NUMERICAL SOLUTIONS OF SOME FLUID DYNAMICAL PROBLEMS** **9**

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

**Practical**

Numerical solution for CD nozzle isentropic flows and local similar solutions of boundary layer equations. **6**

**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.

**Practical**

Elliptic grid generation using Laplace's equations for geometries like airfoil and CD nozzle. **8**

**UNIT III                  TRANSONIC RELAXATION TECHNIQUES** **9**

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

**Practical**

Numerical solution of 1-D conduction- convection energy equation using time dependent methods using both implicit and explicit schemes – application of time split method for the above equation and comparison of the results. **8**

**UNIT IV                  TIME DEPENDENT METHODS** **9**

Stability of solution, Explicit methods, Time split methods, Approximate factorization scheme, Unsteady transonic flow around airfoils. Some time dependent solutions of gas dynamic problems.

**Practical**

Numerical solution of unsteady 2-D heat conduction problems using SLOR methods **4**

## **UNIT V          PANEL METHODS**

**9**

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

### **Practical**

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.

**4**

**L : 45, P : 30    TOTAL NUMBER OF PERIODS:    75**

### **TEXT BOOKS**

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.

### **REFERENCES**

1. T.K. Bose, "Computation Fluid Dynamics" Wiley Eastern Ltd., 1988.
2. H.J. Wirz and J.J. Smeldern "Numerical Methods in Fluid Dynamics", McGraw-Hill & Co., 1978.
3. John D. Anderson, JR" Computational Fluid Dynamics", McGraw-Hill Book Co., Inc., New York, 1995.

**OBJECTIVE**

To familiarize the students in basic aerodynamics and use of wind tunnels.

**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 measurement using wind tunnel balance for various models
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

**OBJECTIVE**

To bring awareness on experimental method of finding the response of the structure to different types of load.

**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.

**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- Acoustic emission technique.

**L : 45, TOTAL : 45**

### **TEXT BOOKS**

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.

### **REFERENCES**

1. M. Hetenyi, "Handbook of Experimental Stress Analysis", John Wiley & Sons Inc., New York, 1980.
2. G.S. Holister, "Experimental Stress Analysis, Principles and Methods", Cambridge University Press, 1987.
3. A.J. Durelli and V.J. Parks, "Moire Analysis of Strain", Prentice Hall Inc., Englewood Cliffs, New Jersey, 1980.







**OBJECTIVE**

To introduce and develop the basic concept of aircraft design.

Each student is assigned the design of an Airplane (or Helicopter or any other flight vehicle), for given preliminary specifications. The following are the assignments to be carried out:

**UNIT I REVIEW OF DEVELOPMENTS IN AVIATION 6**

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

**UNIT II POWER PLANT TYPES AND CHARACTERISTICS 6**

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

**UNIT III PRELIMINARY DESIGN 6**

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

**UNIT IV SPECIAL PROBLEMS 6**

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

**UNIT V STRUCTURAL DESIGN 6**

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.

**PRACICALS**

Conceptual design of an aircraft for given specifications. **30**

**L : 30, P : 30 – TOTAL NUMBER OF PERIODS : 60**

**TEXT BOOKS**

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.

**REFERENCES**

1. E. Torenbeek, "Synthesis of Subsonic Airplane Design", Delft University Press, London, 1976.
2. H.N.Kota, "Integrated design approach to Design fly by wire" Lecture notes Interline Pub. Bangalore, 1992.
3. A.A. Lebedenski, "Notes on airplane design", Part-I, I.I.Sc., Bangalore, 1971.



**OBJECTIVE:**

To present the basic ideas of evolution, performance and associated stability problems of helicopter.

- UNIT I INTRODUCTION 7**  
Types of rotorcraft – autogiro, 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,

**L : 45, TOTAL NUMBER OF PERIODS: 45**

**TEXT BOOKS**

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.

**REFERENCES**

1. John Fay, “The Helicopter”, Himalayan Books, New Delhi, 1995.
2. Lalit Gupta, “Helicopter Engineering”, Himalayan Books, New Delhi, 1996.
3. Lecture Notes on “Helicopter Technology”, Department of Aerospace Engineering, IIT –Kanpur and Rotary Wing aircraft R&D center, HAL, Bangalore, 1998.

**AE 9156**

**THEORY OF PLATES AND SHELLS**

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

**OBJECTIVE:**

To study the behaviour of the 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.

**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.

**L :45 –TOTAL NUMBER OF PERIODS : 45**

**TEXT BOOKS**

1. Timoshenko, S.P. Winowsky. S., and Kreger, Theory of Plates and Shells, McGraw Hill Book Co., 1990.
2. T.K.Varadan & K. Bhaskar, "Analysis of plates – Theory and problems", Narosha Publishing Co., 1999.

**REFERENCES**

1. Flugge, W. Stresses in Shells, Springer – Verlag, 1985.
2. Timoshenko, S.P. and Gere, J.M., Theory of Elastic Stability, McGraw Hill Book Co. 1986.
3. Harry Kraus, 'Thin Elastic Shells', John Wiley and Sons, 1987.

**OBJECTIVE****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 and forced vibrations of systems with finite degrees of freedom – Damped oscillations – D'Alembert's principle – Hamilton's principle – Lagrangean equations of motion and 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 – Rayleigh – Ritz method – Coupled natural modes – Effect of rotary inertia and shear on lateral vibrations of beams – Natural vibrations of plates.

**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.

**L : 45 - TOTAL NUMBER OF PERIODS: 45**

**TEXT BOOKS**

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.

**REFERENCES**

1. R.K. Vierck, "Vibration Analysis", 2nd Edition, Thomas Y. Crowell & Co., Harper & Row Publishers, New York, U.S.A., 1989.
2. S.P. Timoshenko and D.H. Young, "Vibration Problems in Engineering", John Willey & Sons Inc., 1984.
3. Von. Karman and A.Biot, "Mathematical Methods in Engineering", McGraw-Hill Book Co., New York, 1985.

**OBJECTIVE**

To 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 coefficients. Coupled oscillations.

**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.

**L : 45 – TOTAL NUMBER OF PERIODS : 45**

**TEXT BOOKS**

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.

**REFERENCES**

1. R.L. Bisplinghoff, H.Ashley, and R.L. Halfmann, “Aeroelasticity”, II Edition Addison Wesley Publishing Co., Inc., 1996.
2. R.H. Scanlan and R.Rosenbaum, “Introduction to the study of Aircraft Vibration and Flutter”, Macmillan Co., New York, 1981.
3. R.D.Blevins, “Flow Induced Vibrations”, Krieger Pub Co., 2001



**UNIT I TEMPERATURE EQUATIONS & AERODYNAMIC HEATING 9**

For condition, 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**

Thermal stresses in axially loaded members, beams with varying cross sections. Effect of temperature in thin cylinders.

**UNIT IV THERMAL STRESSES IN PLATES 9**

Membrane thermal stresses – Circular plates – Rectangular plates – Bending thermal stresses – Thick plates with temperature varying along thickness – Thermal vibration of plates.

**UNIT V SPECIAL TOPICS & MATERIALS 9**

Thermal bucking, Fatigue and shock applications – High temperature effects on material properties.

**L : 45 - TOTAL NUMBER OF PERIODS: 45**

**TEXT BOOKS**

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.

**REFERENCE**

1. D.J. Johns, “Thermal Stress Analysis”, Pergamon Press, Oxford, 1985.



**OBJECTIVE**

To 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 – 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.

**L : 45 – TOTAL NUMBER OF PERIODS : 45**

**TEXT BOOKS**

1. S.P. Timoshenko and J.N. Goodier, Theory of Elasticity, McGraw-Hill, 1985.
2. E. Sechler, "Elasticity in Engineering" John Wiley & Sons Inc., New York, 1980.

**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

**OBJECTIVE:**

To present the basic ideas of hypersonic flow and the associated problem areas.

**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.

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

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

**L : 45 - TOTAL NUMBER OF PERIODS: 45**

**TEXT BOOKS**

1. John D. Anderson, Jr, Hypersonic and High Temperature Gas Dynamics, McGraw-Hill Series, New York, 1996.

**REFERENCES**

1. John.D.Anderson, Jr., Modern Compressible Flow with Historical perspective Hypersonic Series.
2. William H. Heiser and David T. Pratt, Hypersonic Air Breathing propulsion, AIAA Education Series.
3. John T. Bertin, Hypersonic Aerothermodynamics, 1994 AIAA Inc., Washington D.C.

**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.

**L : 45 – TOTAL NUMBER OF PERIODS : 45**

**TEXT BOOKS**

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.

**REFERENCES**

1. William H. Heiser and David T. Pratt, Hypersonic Air breathing propulsion, AIAA Education Series.
2. John T. Bertin, Hypersonic Aerothermodynamics publishers - AIAA Inc., Washington, D.C., 1994.
3. T.K.Bose, High Temperature Gas Dynamics,

**OBJECTIVE**

To study 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 – Supercritical charging and subcritical discharging – Subcritical charging and subcritical discharging – Subcritical charging and supercritical discharging.

**UNIT II RAMJETS AND AIR AUGMENTED ROCKETS 8**

Preliminary performance calculations – Diffuser design and hypersonic inlets – combustor and nozzle design – air augmented rockets – engines with supersonic combustion.

**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 radioisotope propulsion systems.

**UNIT V ELECTRIC AND ION PROPULSION 8**

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

**L : 45 - TOTAL NUMBER OF PERIODS: 45**

**TEXT BOOKS**

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.

**REFERENCES**

1. Fortescue and Stark, Spacecraft Systems Engineering, 1999.
2. Cumpsty, Jet propulsion, Cambridge University Press, 2003.

**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 MEASUREMENTS 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 Schlieren (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.

**L : 45 – TOTAL NUMBER OF PERIODS : 45**

**TEXT BOOKS**

1. Rathakrishnan, E., "Instrumentation, Measurements, and Experiments in Fluids," CRC Press – Taylor & Francis, 2007.

**REFERENCES**

1. Robert B Northrop, "Introduction to Instrumentation and Measurements", Second Edition, CRC Press, Taylor & Francis, 2006.

- UNIT I THE ATMOSPHERE: 6**  
 Atmospheric Circulation – Stability of atmospheres – definitions & implications – Effects of friction – Atmospheric motion – Local winds, Building codes, Terrains different types.
- UNIT II ATMOSPHERIC BOUNDARY LAYER: 9**  
 Governing Equations – Mean velocity profiles, Power law, logarithmic law wind speeds, Atmospheric turbulence profiles – Spectral density function – Length scale of turbulence, Roughness parameters simulation techniques in wind tunnels.
- UNIT III BLUFF BODY AERODYNAMICS: 10**  
 Governing Equations – Boundary layers and separations – Wake and Vortex formation two dimensional – Strouhal Numbers, Reynolds numbers – Separation and Reattachments Oscillatory Flow patterns Vortex shedding flow switching – Time varying forces to wind velocity in turbulent flow – Structures in three dimensional
- UNIT IV WIND LOADING 10**  
 Introduction, Analysis and synthesis loading coefficients, local & global coefficients pressure shear stress coefficients, force and moment coefficients – Assessment methods – Quasi steady method – Peak factor method – Extreme value method
- UNIT V AEROELASTIC PHENOMENA: 10**  
 Vortex shedding and lock in phenomena in turbulent flows, across wind galloping wake galloping - Torsional divergence, along wind galloping of circular cables, cross wind galloping of circular cables, Wind loads & their effects on tall structures – Launch vehicles

**L: 45, TOTAL NUMBER OF PERIODS: 45**

#### **TEXT BOOKS**

1. Emil Simiu & Robert H Scanlan, Wind effects on structures - fundamentals and applications to design, John Wiley & Sons Inc New York, 1996.

#### **REFERENCES:**

1. Tom Lawson Building Aerodynamics Imperial College Press London, 2001
2. N J Cook, Design Guides to wind loading of buildings structures Part I & II, Butterworths, London, 1985
3. IS: 875 (1987) Part III Wind loads, Indian Standards for Building codes.



**UNIT I PRINCIPLES OF MODEL TESTING: 6**  
 Buckingham Theorem – Non dimensional numbers – Scale effect – Geometric Kinematics and Dynamic similarities.

**UNIT II WIND TUNNELS: 8**  
 Classification – special problems of testing in subsonic, transonic, supersonic and hypersonic speed regions – Layouts – sizing and design parameters.

**UNIT III CALIBRATION OF WIND TUNNELS: 10**  
 Test section speed – Horizontal buoyancy – Flow angularities – Turbulence measurements – Associated instrumentation – Calibration of supersonic tunnels.

**UNIT IV WIND TUNNEL MEASUREMENTS: 12**  
 Steady and Unsteady Pressure and Velocity measurements – Force measurements – Three component and six component balances – Internal balances – Principles of Hotwire Anemometer.

**UNIT V FLOW VISUALIZATION: 9**  
 Smoke and Tuft techniques – Dye injection special techniques – Optical methods of flow visualization.

**L : 45 – TOTAL NUMBER OF PERIODS: 45**

#### **TEXT BOOKS**

1. Rae, W.H. and Pope, A., Low Speed Wind Tunnel Testing, John Wiley Publications, 1984.
2. Pope, A., and Goin, L., High Speed Wind Tunnel Testing, John Wiley, 1985.

#### **REFERENCES**

1. P. Bradshaw, Experimental Fluid Mechanics, Pergamon Press, Macmillan Co., New York, 1964.

**OBJECTIVE**

To introduce basic concepts of design and trajectory estimation of rockets and missiles.

**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 life time – satellite 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 – staging of rockets.

**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.

**L : 45, TOTAL NUMBER OF PERIODS : 45**

**TEXT BOOKS**

1. G.P. Sutton, “Rocket Propulsion Elements”, John Wiley & Sons Inc., New York, 5<sup>th</sup> Edition, 1986.
2. J.W. Cornelisse, “Rocket Propulsion and Space Dynamics”, J.W. Freeman & Co., Ltd., London, 1982.

**REFERENCES**

1. Van de Kamp, “Elements of astromechanics”, Pitman Publishing Co., Ltd., London, 1980.
2. E.R. Parker, “Materials for Missiles and Spacecraft”, McGraw-Hill Book Co., Inc., 1982.

**OBJECTIVE**

To 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.

**L : 45 – TOTAL NUMBER OF PERIODS : 45**

**TEXT BOOKS**

1. R.M. Jones, "Mechanics of Composite Materials", 2<sup>nd</sup> 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

**REFERENCES**

1. G.Lubin, "Hand Book on Fibre glass and advanced plastic composites", Van Nostrand Co., New York, 1989.
2. B.D. Agarwal and L.J. Broutman, "Analysis and Performance of fiber composites", John-Wiley and Sons, 1990.