

**AFFILIATED INSTITUTIONS**  
**ANNA UNIVERSITY : : CHENNAI**  
**REGULATIONS - 2009**  
**CURRICULUM**  
**M.E. AERONAUTICAL ENGINEERING**  
**SEMESTER I**

SL.No.	COURSE CODE	COURSE TITLE	L	T	P	C
<b>THEORY</b>						
1	MA 9322	<a href="#">Applied Mathematics for Aeronautical Engineering</a>	3	1	0	4
2	AE 9311	<a href="#">Aerodynamics</a>	3	1	0	4
3	AE 9312	<a href="#">Aircraft Structures</a>	3	1	0	4
4	AE 9313	<a href="#">Aerospace Propulsion</a>	3	1	0	4
5	AE 9314	<a href="#">Theory of Vibrations</a>	3	0	0	3
6	E1	Elective I	3	0	0	3
<b>PRACTICAL</b>						
7	AE 9315	<a href="#">Structures Laboratory</a>	0	0	4	2
<b>TOTAL</b>			<b>18</b>	<b>4</b>	<b>4</b>	<b>22</b>

**LIST OF ELECTIVES**

S.NO	COURSE CODE	COURSE TITLE	L	T	P	C
1.	AE 9001	<a href="#">Experimental Stress Analysis</a>	3	0	0	3
2.	AE 9002	<a href="#">Numerical Heat Transfer</a>	2	0	2	3
3.	AE 9003	<a href="#">Boundary Layer Theory</a>	3	0	0	3
4.	AE 9004	<a href="#">Aircraft Design</a>	2	0	2	3
5.	AE 9005	<a href="#">Industrial Aerodynamics</a>	3	0	0	3
6.	AE 9006	<a href="#">Helicopter Aerodynamics</a>	3	0	0	3
7.	AE 9007	<a href="#">Theory of Plates and Shells</a>	3	0	0	3
8.	AE 9008	<a href="#">Structural Dynamics</a>	3	0	0	3
9.	AE 9009	<a href="#">Aero elasticity</a>	3	0	0	3
10.	AE 9010	<a href="#">High Temperature Problems in Structures</a>	3	0	0	3
11.	AE 9011	<a href="#">Fatigue and Fracture Mechanics</a>	3	0	0	3
12.	AE 9012	<a href="#">Theory of Elasticity</a>	3	0	0	3
13.	AE 9013	<a href="#">Hypersonic Aerodynamics</a>	3	0	0	3
14.	AE 9014	<a href="#">High Temperature Gas Dynamics</a>	3	0	0	3
15.	AE 9015	<a href="#">Advanced Propulsion Systems</a>	3	0	0	3
16.	AE 9016	<a href="#">Experimental Methods in Fluid Mechanics</a>	3	0	0	3
17.	AE 9017	<a href="#">Wind Engineering</a>	3	0	0	3
18.	AE 9018	<a href="#">Wind Tunnel Techniques</a>	3	0	0	3
19.	AE 9019	<a href="#">Rocketry and Space Mechanics</a>	3	0	0	3
20.	AE 9020	<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.

**AE 9311**

**AERODYNAMICS**

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

## 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 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

**AE 9313**

**AEROSPACE PROPULSION**

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

**OBJECTIVE**

To understand the principles of operation and design of aircraft and spacecraft power plants.

**UNIT I ELEMENTS OF AIRCRAFT PROPULSION 12**

Classification of power plants based on 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 / 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 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 COMPRESSORS AND TURBINES 12**

Centrifugal compressor – Work done and pressure rise – Velocity diagrams – Elementary theory of axial flow compressor – degree of reaction – Impulse and reaction gas turbines – Velocity triangles – Choice of blade profile, pitch and chord.

**UNIT V ROCKET 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 – Thrust control in liquid rockets.

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

**TEXT BOOKS**

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

**REFERENCES**

1. G.C. Oates, "Aerothermodynamics of Aircraft Engine Components", AIAA Education Series, 1985.
2. G.P. Sutton, "Rocket Propulsion Elements", John Wiley & Sons Inc., New York, 5<sup>th</sup> Edition, 1986.
3. 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.

**AE 9314**

**THEORY OF VIBRATIONS**

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

**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.



**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 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.

**PRACTICALS**

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.

**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, “Análýsis 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.

**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



- 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
- UNIV 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.