St. PETER'S UNIVERSITY

St. Peter's Institute of Higher Education and Research
(Declared under section 3 of UGC Act 1956)
Avadi, Chennai – 600 054.

M.E. (AERONAUTICAL ENGINEERING) PROGRAMME

(I to IV SEMESTERS)

REGULATIONS AND SYLLABI

REGULATIONS – 2013

(Effective from the Academic Year 2013-'14)

M.E. (AERONAUTICAL ENGINEERING) PROGRAMME

(Regulations 2013)

(Effective from the Academic Year 2013-‘2014)

1. **Eligibility:** Candidates who passed B.E / B.Tech. (Aeronautical / Mechanical / Aerospace/ Civil/ Mechatronics) of the University or A.M.I.E. in the concerned subject or any other equivalent examination thereto are eligible for admission to Two Year M.E. (Aeronautical Engineering) Programme.

2. **Duration:** Two Years Comprising 4 Semesters. Each semester has a minimum 90 working days with a minimum of 5 hours a day.

3. **Medium:** English is the medium of instruction and examination.

4. **Weightage for Continuous and End Assessment:** The weightage for Continuous assessment (CA) and End Assessment (EA) be 25 : 75 unless the ratio is specifically mentioned in the scheme of Examinations.

5. **Credit System:** Credit system be followed with 18 credits for each semester and credit each is equivalent to 25 hours of effective study provided in the Time Table.

6. **SCHEME OF EXAMINATION**

SEMESTER I

Code No.	Course Title	CREDIT	Marks		
			CA	EA	Total
Theory					
113ARPT01	**APPLIED MATHEMATICS**	2	25	75	100
113ARPT02	Aerodynamics	2	25	75	100
113ARPT03	Aircraft Structural Mechanics	3	25	75	100
113ARPT04	Aerospace Propulsion	3	25	75	100
113ARPT05	Theory of Vibrations	3	25	75	100
113ARPT07	**Elective I: Aircraft Design**	3	25	75	100
Practical					
113ARPP01	Aerodynamics Laborator0079	2	25	75	100
	Total	**18**	**175**	**525**	**700**

II Semester

Code No.	Course Title	CREDIT	Marks		
			CA	EA	Total
Theory					
213ARPT01	Flight Mechanics	2	25	75	100
213ARPT02	Finite Element Methods	2	25	75	100
213ARPT03	Computational Fluid Dynamics in Aerospace Engineering	3	25	75	100
213ARPT04	Composite Materials and Structures	3	25	75	100
	Elective II:	3	25	75	100
	Elective III:	3	25	75	100
Practical					
213ARPP01	Structures Laboratory	2	25	75	100
	Total	**18**	**175**	**525**	**700**

III Semester

Code No.	Course Title	CREDIT	Marks		
			CA	EA	Total
Theory					
	Elective IV :	3	25	75	100
	Elective V :	3	25	75	100
Project					
313ARPP01	Project Work – Phase I	12	25	75	100
	Total	**18**	**75**	**225**	**300**

IV Semester

Code No.	Course Title	CREDIT	Marks		
			CA	EA	Total
Project					
413ARPP01	Project Work – Phase II	18	25	75	100
	Total	**18**	**25**	**75**	**100**

LIST OF ELECTIVES

S.No.	Course Code	Course Title	CREDIT (marks)
		Semester I	
1.	113ARPT06	Boundary Layer Theory	3
2.	113ARPT07	**Aircraft Design**	3
3.	113ARPT08	Industrial Aerodynamics	3
4.	113ARPT09	Helicopter Aerodynamics	3
5.	113ARPT10	Structural Dynamics	3
6.	113ARPT11	Aero Elasticity	3
		Semester II	
7.	213ARPT05	Theory of Plates and Shells	3
8.	213ARPT06	High Temperature Problems in Structures	3
9.	213ARPT07	Fatigue and Fracture Mechanics	3
10.	213ARPT08	Theory of Elasticity	3
11.	213ARPT09	Hypersonic Aerodynamics	3
12.	213ARPT10	High Temperature Gas Dynamics	3
13.	213ARPT11	Wind Power Engineering	3
		Semester III	
15.	313ARPT01	Experimental Stress Analysis	3
16.	313ARPT02	Computational Heat Transfer	3
17.	313ARPT03	Advanced Propulsion Systems	3
18.	313ARPT04	Experimental Aerodynamics	3
19.	313ARPT05	Rocketry and Space Mechanics	3
20.	313ARPT06	High Speed Jet Flows	3
21.	313ARPT07	Combustion in Jet and Rocket Engines	3
22.	313ARPT08	Propeller Aerodynamics	3
23	313ARPT09	Aerospace Guidance and Control	3

7. **Passing Requirements:** The minimum pass mark (raw score) be 50% in End Assessment (EA) and 50% in Continuous Assessment (CA) and End Assessment (EA) put together. No minimum mark (raw score) in Continuous Assessment (CA) be prescribed unless it is specifically mentioned in the Scheme of Examination.

8. **Grading System:** Grading System on a 10 Point Scale be followed with 1 mark = 0.1 Grade point to successful candidates as given below.

CONVERSION TABLE

(1 mark = 0.1 Grade Point on a 10 Point Scale)

Range of Marks	**Grade Point**	**Letter Grade**	**Classification**
90 to 100	9.0 to 10.0	O	First Class
80 to 89	8.0 to 8.9	A	First Class
70 to 79	7.0 to 7.9	B	First Class
60 to 69	6.0 to 6.9	C	First Class
50 to 59	5.0 to 5.9	D	Second Class
0 to 49	0 to 4.9	**F**	**Reappearance**

Procedure for Calculation

Cumulative Grade Point Average (CGPA) $= \frac{\text{Sum of Weighted Grade Points}}{\text{Total Credits}}$

$$= \frac{\sum (CA+EA)\,C}{\sum C}$$

Where Weighted Grade Points in each Course = Grade Points (CA+EA) multiplied by Credits

$$= (CA+EA)C$$

Weighted Cumulative Percentage of Marks(WCPM) = CGPAx10

C- Credit, CA-Continuous Assessment, EA- End Assessment

9. **Pattern of the Question Paper:** The question paper for End Assessment will be set for three hours and for the maximum of 100 marks with following divisions and details.

   Part A: 10 questions (with equal distribution to all units in the syllabus). Each question carries 2 marks.

   Part B: 5 questions with either or type (with equal distribution to all units in the syllabus).Each question carries 16 marks. The total marks scored by the candidates will be reduced to the maximum prescribed in the Regulations.

10. **Effective Period of Operation for the Arrear Candidates :** Two Year grace period is provided for the candidates to complete the arrear examination, if any.

Registrar

11. **Syllabus**

113ARPT01 - APPLIED MATHEMATICS

OBJECTIVES:

- To develop the ability to apply the concepts of Matrix theory and Liner programming in Engineering problems.
- To familiarize the students in calculus of variations and solve problems using Fourier transforms associated with engineering applications.
- To expose the students to conformal mapping

UNIT I CALCULUS OF VARIATION

Introduction — Euler's equation — several dependent variables Lagrange's equations of Dynamics — Integrals involving derivatives higher that the first — Problems with constraints — Direct methods and eigen value problems.

UNIT II MATRIX THEORY

Eigen values using QR transformations — generalized eigenvectors — canonical forms — singular value decomposition and applications — pseudo inverse — least square approximations.

UNIT III LINEAR PROGRAMMING PROBLEM

Graphical method – simplex method – Big M Technique – Integer programming.

UNIT I V FOURIER TRANSFORM TECHNIQUES FOR PARTIAL DIFFERENTIAL EQUATIONS

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 V CONFORMAL MAPPING AND APPLICATIONS

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

REFERENCES

1. Gupta, A.S, Calculus of variations with Applications, Prentice – Hall of India New Delhi, 1997.
2. Broson, R., Matrix operations, Schaum's outline series, McGraw Hill, New York, 1989.
3. Taha H.A, "Operation Research – An Introduction", Prentice Hall of India, 2001.
4. Andrew L.C. and Shivamoggi B.K., "Integral Transforms for Engineers", Prentice Hall of India Pvt. Ltd., New Delhi, 2003.
5. Mathews J.H. and Howell R.W., "Complex Analysis for Mathematics and Engineering", Narosa Publishing House, New Delhi,1997

113ARPT02 - AERODYNAMICS

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
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
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
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
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
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.

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.

113ARPT03 - AIRCRAFT STRUCTURAL MECHANICS

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

UNIT II SHEAR FLOW IN OPEN SECTIONS
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
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
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
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.

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.

113ARPT04 - AEROSPACE PROPULSION

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

UNIT V ROCKET AND ELECTRIC PROPULSION
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.

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.

113ARPT05 THEORY OF VIBRATIONS

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

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.

113ARPP01 - AERODYNAMICS LABORATORY L T P C

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

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

213ARPT01 - AO7201 FLIGHT MECHANICS

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
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
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
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
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
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.

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.

213ARPT02 - FINITE ELEMENT METHODS L T P C

OUTCOME:
Upon completion of the course, students will learn the concept of numerical analysis of structural Components.

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

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.

213ARPT03 COMPUTATIONAL FLUID DYNAMICS IN AEROSPACE ENGINEERING

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
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
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
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
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.

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

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.

213ARPT04 - COMPOSITE MATERIALS AND STRUCTURES

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

UNIT I INTRODUCTION
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
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
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
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
Netting analysis- Failure criteria-Flexural rigidity of Sandwich beams and plates – composite repair- AE technique..

213ARPP01 - STRUCTURES LABORATORY

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.

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

113ARPT06 - BOUNDARY LAYER THEORY L T P C

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
Navier-Stokes Equations, Creeping motion, Couette flow, Poiseuille flow through ducts, Ekman drift.

UNIT II LAMINAR BOUNDARY LAYER
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
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
Approximate integral methods, digital computer solutions – Von Karman – Polhausen method.

UNIT V THERMAL BOUNDARY LAYER
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.

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.

113ARPT07 - AIRCRAFT DESIGN

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

UNIT I REVIEW OF DEVELOPMENTS IN AVIATION
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
Characteristics of different types of power plants – Propeller characteristics and selection – Relative merits of location of power plant.

UNIT III PRELIMINARY DESIGN
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
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
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.

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.

113ARPT08 - INDUSTRIAL AERODYNAMICS

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

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

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

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.

113ARPT09 - HELICOPTER AERODYNAMICS

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
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
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
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
Helicopter Trim, Static stability – Incidence disturbance, forward speed disturbance, angular velocity disturbance, yawing disturbance, Dynamic Stability.

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

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.

113ARPT10 - STRUCTURAL DYNAMICS

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

UNIT II PRINCIPLES OF DYNAMICS
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
Equations of motion for free vibrations. Solution of Eigen value problems – Normal coordinates and orthogonality conditions of eigen vectors.

UNIT IV ENERGY METHODS
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
Approximate methods of evaluating the eigen values and the dynamic response of continuous systems. Application of Matrix methods for dynamic analysis.

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.

113ARPT11 - AERO ELASTICITY

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

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

213ARPT05 - THEORY OF PLATES AND SHELLS

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
Classical Plate Theory – Assumptions – Differential Equations – Boundary Conditions.

UNIT II PLATES OF VARIOUS SHAPES
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
Stability and Free Vibration Analysis of Rectangular Plates with various end conditions.

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

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

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.

213ARPT06 - HIGH TEMPERATURE PROBLEMS IN STRUCTURES

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
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
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
Analysis of bar, plane truss and beam under mechanical loads and temperature. Thermal stress analysis of thin cylinder.

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

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

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.

213ARPT07 - FATIGUE AND FRACTURE MECHANICS

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

UNIT I FATIGUE OF STRUCTURES
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
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
Phase in fatigue life – Crack initiation – Crack growth – Final fracture – Dislocations – Fatigue fracture surfaces.

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

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.

213ARPT08 - THEORY OF ELASTICITY

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
Definition, notations and sign conventions for stress and strain – Stress - strain relations, Straindisplacement
relations- Elastic constants.

UNIT II BASIC EQUATIONS OF ELASTICITY
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
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
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
Coulomb's theory-Navier's theory-Saint Venant's Semi-Inverse method – Torsion of Circular, Elliptical and Triangular sections - Prandtl's theory-Membrane analogy.

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.

213ARPT09 - HYPERSONIC AERODYNAMICS

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
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
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`
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 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
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.

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.

213ARPT10 - HIGH TEMPERATURE GAS DYNAMICS

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

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

UNIT III KINETIC THEORY AND HYPERSONIC FLOWS
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
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
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.

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,

213ARPT11 - WIND POWER ENGINEERING

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

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

UNIT II WIND CHARACTERISTICS AND RESOURCES
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
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
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
Overview- Wind turbine siting - Installation and operation- Wind farms- Overview of wind energy economics-Electromagnetic interference-noise-Land use impacts - Safety.

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.

313ARPT01 - EXPERIMENTAL STRESS ANALYSIS

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

UNIT II ELECTRICAL RESISTANCE STRAIN GAUGES
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
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
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
Radiography- Ultrasonics- Magnetic particle inspection- Fluorescent penetrant technique-Eddy current testing– thermography– MICRO FOCUS CT scan.

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.

313ARPT02 - COMPUTATIONAL HEAT TRANSFER

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

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

UNIT II CONDUCTIVE HEAT TRANSFER
General 3D-heat conduction equation in Cartesian, cylindrical and spherical coordinates.
Computation(FDM) of One –dimensional steady state heat conduction –with Heat generationwithout 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
Introduction to Implicit, explicit Schemes and crank-Nicolson Schemes Computation(FDM) of One –dimensional un-steady heat conduction –with heat Generation-without Heat generation - 2Dtransient 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
Convection- Numerical treatment(FDM) of steady and unsteady 1-D and 2-d heat convectiondiffusion steady-unsteady problems- Computation of thermal and Velocity boundary layer flows.
Upwind scheme. Stream function-vorticity approach-Creeping flow.

UNIT V RADIATIVE HEAT TRANSFER
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.

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.

313ARPT03 - ADVANCED PROPULSION SYSTEMS

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

UNIT III SCRAMJET PROPULSION SYSTEM
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
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
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.

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.

313ARPT04 - EXPERIMENTAL AERODYNAMICS

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

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.

313ARPT05 - ROCKETRY AND SPACE MECHANICS L T P C

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

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.
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313ARPT06 - HIGH SPEED JET FLOWS L T P C

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
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
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
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 isobaric) contours, Shock cell structure in underexpanded and overexpanded jets, Mach discs.

UNIT IV BOUNDARY LAYER CONCEPT
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
Introduction to Acoustic – Types of noise – Source of generation- Traveling wave solutionstanding wave solution – multi-dimensional acoustics -Noise suppression techniques– applications to problems.

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.

313ARPT07 - COMBUSTION IN JET AND ROCKET ENGINES

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

UNIT I THERMODYNAMICS OF COMBUSTION
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
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
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
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
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.

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.

313ARPT08 - PROPELLER AERODYNAMICS

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

UNIT I AIR SCREW THEORY
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
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 solutionefficiency-numerical results.

UNIT III THE BLADE ELEMENT THEORY
Primitive Blade Element Theory- Efficiency of the blade element- Blade interface- The vortex system of a propeller- induced velocity- The airfoil characteristics- Multi plane Interferencecascade of airfoils – Airfoil characteristics in a cascade.

UNIT IV THE VORTEX THEORY
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
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.

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.

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

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

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

UNIT III LONGITUDINAL AUTOPILOT
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
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
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

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.

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