UNIVERSITY OF KERALA

B. TECH. DEGREE COURSE

(2013 SCHEME)

SYLLABUS FOR

VI SEMESTER

AERONAUTICAL ENGINEERING

SCHEME -2013

VI SEMESTER
AERONAUTICAL ENGINEERING (S)

Course No	Name of subject	Credits	Weekly load, hours			C A Marks	Exam Duration Hrs	U E Max Marks	Total Marks
			L	T	D/P				
13.601	Aircraft Design (S)	4	3	1	-	50	3	100	150
13.602	Computational Methods in Engineering (S)	4	3	1	-	50	3	100	150
13.603	Propulsion-I (S)	3	2	1	-	50	3	100	150
13.604	Heat and Mass Transfer (MSU)	4	3	1	-	50	3	100	150
13.605	Control Systems (S)	4	3	1	-	50	3	100	150
13.606	Elective II	4	3	1	-	50	3	100	150
13.607	Low Speed Aerodynamics Lab (S)	3	-	-	3	50	3	100	150
13.608	Fluid & Flight Mechanics Lab (S)	3	-	-	3	50	3	100	150
	Total	**29**	**17**	**6**	**6**	**400**		**800**	**1200**

13. 606 Elective II

13.606.1	High Speed Aerodynamics (S)
13.606.2	Wind Tunnel Technology (S)
13.606.3	FEM (S)
13.606.4	Helicopter Aerodynamics (S)
13.606.5	Control Navigation and Guidance (S)
13.606.6	Advanced Mechanics of Solids (S)

13.501 AIRCRAFT DESIGN(S)

Teaching Scheme: 3(L) - 1(T) - 0(P) **Credits**: 4

Course Objective:

To understand the conceptual design and detailed design of Aircrafts.

Module – I

Overview of design process: Introduction, Phases of Aircraft design, Aircraft conceptual design process. Introduction to Weight estimations - Takeoff weight build up, Empty-Weight estimation, Fuel-Fraction estimation, Take-off weight calculation.

Module – II

Wing layouts and their characteristics: Type of Wings, Wing Geometry, Wing Loading, Selection of Thrust to Weight and Wing Loading, Airfoil Selection. Introduction to Tail Geometry and Arrangements, Wing/Tail Layout and Loft.

Module – III

Fuselage layout and loft: Introduction, Conic Lofting, Conic Fuselage Development, Flat-Wrap Fuselage Lofting, Circle to Square Adapter, Fuselage Loft Verification, Aircraft Layout Procedures, Wetted Area Determination, Volume Determination.

Module – IV

Propulsion and landing gear systems: Propulsion Systems- Propulsion selection, Jet engine Integration, Propeller Engine Integration, Thrust Considerations, Performance of Piston Engine and Turboprop Engine, Fuel Systems.

Landing gear – Landing Gear Arrangements, Tire Sizing, Shock Absorbers, Castoring- Wheel Geometry, Gear-Retraction Geometry, Seaplanes, Subsystems.

Introduction to fatigue: Safe life and fail-safe structures, Designing against fatigue, Fatigue strength of components, Prediction of aircraft fatigue life and crack propagation.

References:

1. Daniel P Raymer, *Airplane Design- A Conceptual Approach*, AIAA Education Series, USA, 1999.
2. Barrois W. and E.L. Ripely, *Fatigue of Aircraft Structure*, Pergamon Press, Oxford, 1913.
3. Stinton D., *The Design of Airplane,* GRANADA, UK, 2000.
4. Nikolai L.M., *Fundamentals of Aircraft Design,* Univ. of Dayton, Ohio, 1975.

5. Bertin and Smith, *Aerodynamics for Engineers,* Prentice Hall, 1988.
6. Scheler E.E. and L.G. Dunn, *Airplane Structural Analysis and Design,* John Wiley & Sons, 1963.

Internal Continuous Assessment *(Maximum Marks-50)*

50% - Tests (minimum 2)
30% - Assignments (minimum 2) such as home work, problem solving, quiz, literature survey, seminar, term-project, software exercises, etc.
20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours *Maximum Total Marks: 100*

The question paper shall consist of 2 parts.

Part A (20 marks) - Five Short answer questions of 4 marks each. All questions are compulsory. There should be at least one question from each module and not more than two questions from any module.

Part B (80 Marks) - Candidates have to answer one full question out of the two from each module. Each question carries 20 marks.

Course Outcome:

After successful completion of this course, the students will be familiar with the concepts of aircraft configuration and its influence on flight performance. Also they will be familiar with the principles of aircraft design from the point of view of technology of production and operating.

13.602 COMPUTATIONAL METHODS IN ENGINEERING (S)

Teaching Scheme: 3(L) - 1(T) - 0(P) **Credits**: 4

Course Objectives:

This course aims at providing the necessary basic concepts of a few numerical methods and give procedures for solving numerically different kinds of problems occurring in engineering and technology.

Module – I

Solution of equations and Eigen value problems: Solution of algebraic and transcendental equations - Fixed point iteration method – Newton Raphson method- Solution of linear system of equations - Gauss elimination method – Pivoting - Gauss Jordan method – Iterative methods of Gauss Jacobi and Gauss Seidel - Matrix Inversion by Gauss Jordan method – Eigen values of a matrix by Power method.

Module – II

Interpolation and approximation: Interpolation with unequal intervals - Lagrange's interpolation – Newton's divided difference interpolation – Cubic Splines - Interpolation with equal intervals - Newton's forward and backward difference formulae.

Numerical differentiation and integration: Approximation of derivatives using interpolation polynomials - Numerical integration using Trapezoidal, Simpson's 1/3 rule – Romberg's method - Two point and three point Gaussian quadrature formulae – Evaluation of double integrals by Trapezoidal and Simpson's 1/3 rules.

Module – III

Initial value problems for ordinary differential Equations Single Step methods - Taylor's series method - Euler's method - Modified Euler's method – Fourth order Runge-Kutta method for solving first order equations - Multi step methods - Milne's and Adams-Bashforth predictor corrector methods for solving first order equations.

Module – IV

Boundary value problems in ordinary and partial Differential equation: Finite difference methods for solving two-point linear boundary value problems - Finite difference techniques for the solution of two dimensional Laplace's and Poisson's equations on rectangular domain – One dimensional heat flow equation by explicit and implicit (Crank Nicholson) methods –One dimensional wave equation by explicit method.

References:

1. Grewal. B. S., and Grewal. J. S., *Numerical methods in Engineering and Science*, Khanna Publishers, New Delhi, 9th Edition, 2007.

2. Gerald. C. F., and Wheatley. P. O., *Applied Numerical Analysis*, Pearson Education, Asia, New Delhi, 6th Edition, 2006.
3. Chapra S. C., and Canale R. P., *Numerical Methods for Engineers*, 5th Edition, Tata McGraw - Hill, New Delhi, 2007.
4. Brian Bradie, *A Friendly Introduction to Numerical Analysis*, Pearson Education, Asia, New Delhi, 2007.
5. Sankara Rao K., *Numerical methods for Scientists and Engineers*, 3rd Edition, Prentice Hall of India Private Ltd., New Delhi, 2007.

Internal Continuous Assessment *(Maximum Marks-50)*

50% - Tests (minimum 2)

30% - Assignments (minimum 2) such as home work, problem solving, quiz, literature survey, seminar, term-project, software exercises, etc.

20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours *Maximum Total Marks: 100*

The question paper shall consist of 2 parts.

Part A (20 marks) - Ten Short answer questions of 2 marks each. All questions are compulsory. There should be at least two questions from each module and not more than three questions from any module.

Part B (80 Marks) - Candidates have to answer one full question out of the two from each module. Each question carries 20 marks.

Course Outcome:

Students successfully completing this course will have a clear perception of the power of numerical techniques, ideas and would be able to demonstrate the applications of these techniques to problems drawn from industry, management and other engineering fields.

13.603 PROPULSION – I (S)

Teaching Scheme: 2(L) - 1(T) - 0(P) **Credits**: 3

Course Objectives :

To introduce basic concepts and salient features of engine components of jet propelled engines which are operated in atmosphere to students. This course is also aimed at making students familiarize with advanced jet propulsion methods like hypersonic propulsion.

Module – I

Fundamentals of gas turbine engines: Basic concepts of air standard cycles. Illustration of working of gas turbine engine - Air-standard Brayton cycle, actual gas turbine engine cycle The thrust equation - Factors affecting thrust - Effect of pressure, velocity and temperature changes of air entering compressor - Methods of thrust augmentation – Characteristics of turboprop, turbofan and turbojet - Performance characteristics.

Combustion chambers: Classification of combustion chambers - various arrangements, simplex and duplex burners. Line design important factors affecting combustion chamber design – Combustion process - Combustion chamber performance - effect of operating variables on performance - Flame tube cooling- Flame stabilization - Use of flame holders - Numerical problems.

Module – II

Subsonic and supersonic inlets for jet engines: Internal flow and Stall in Subsonic inlets - Boundary layer separation - Major features of external flow near a subsonic inlet - Relation between minimum area ratio and external deceleration ratio - Diffuser performance – Supersonic inlets - Starting problem in supersonic inlets - Shock swallowing by area variation – External deceleration - Modes of inlet operation.

Module – III

Nozzles: Theory of flow in isentropic nozzles – design, Convergent nozzles and nozzle choking - Nozzle throat conditions Nozzle efficiency - nozzle operating characteristics for isentropic flow, nozzle flow and shock waves Losses in nozzles - Over expanded and under-expanded nozzles - Ejector and variable area nozzles - Interaction of nozzle flow with adjacent surfaces - Thrust reversal.

Module – IV

Propellers: Ideal momentum theory and blade element theory and their relative merits, numerical problems on the performance of propellers using propeller charts, selection of propellers, fixed, variable and constant speed propellers, prop-fan, material for propellers, shrouded propellers helicopter, rotor in hovering.

References:

1. Philip Hill and Carl Peterson, Mechanics and Thermodynamics of Propulsion, 2nd Edition, Addison -Wesley Publishing Company, Singapore, 1992.
2. George Sutton & Oscar Biblarz, Rocket Propulsion Elements, John Wiley & Sons.
3. Rolls-Royce, Jet Engine, 3rd edition, 1983.
4. Oates, G. C., Aerothermodynamics of Aircraft Engine Components, AIAA Education Series, New York, 1985.
5. Cohen, H, G. F. C. Rogers and H. I. H. Saravanamuttoo, Gas Turbine Theory, Longman, 1989.
6. Mattingly J. D., W.H. Heiser, and D. T. Pratt, Aircraft Engine Design, AIAA Education Series, New York, 2002.
7. Thomas A. Ward, Aerospace Propulsion Systems, John Wiley & Sons,2010
8. *Aircraft Gas Turbine Engine- Operations, Components & Systems, (Jet Propulsion)*, Wexford, 2008.
9. Ahmed F. El Sayed, *Aircraft Propulsion and Gas Turbine Engines*, CRC Press, 2008
10. Tony Giampaolo, *Gas Turbine Handbook: Principles and Practice*, The Fairmont Press Inc., 2009

Internal Continuous Assessment *(Maximum Marks-50)*

50% - Tests (minimum 2)

30% - Assignments (minimum 2) such as home work, problem solving, quiz, literature survey, seminar, term-project, software exercises, etc.

20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours *Maximum Total Marks: 100*

The question paper shall consist of 2 parts.

Part A (20 marks) - Ten Short answer questions of 2 marks each. All questions are compulsory. There should be at least two questions from each module and not more than three questions from any module.

Part B (80 Marks) - Candidates have to answer one full question out of the two from each module. Each question carries 20 marks.

Course Outcome:

Students successfully completing this course are expected to understand the aircraft propulsion systems and to know the details of intake and exhaust systems.

13.604 HEAT AND MASS TRANSFER (MSU)

Teaching Scheme: 3(L) - 1(T) - 0(P) **Credits**: 4

Course Objective:

- *To introduce a basic study of the phenomena of heat and mass transfer, to develop methodologies for solving a wide variety of practical engineering problems,*
- *To apply analytical and numerical methods to solve conduction problems.*
- *To combine thermodynamics and fluid mechanics principles to analyze heat convection processes.*
- *To provide useful information concerning the performance and design complex heat transfer applications, such as heat exchangers and fins*
- *To integrate radiation aspects into real-world global heat transfer problems.*

Module – I

Modes of Heat Transfer: Conduction: Fourier law of heat conduction-Thermal conductivity of solids, liquids and gases-Factors affecting thermal conductivity- Most general heat conduction equation in Cartesian, cylindrical and spherical coordinates One dimensional steady state conduction with and without heat generation conduction through plane walls, cylinders and spheres-variable thermal conductivity conduction shape factor- heat transfer through corners and edges. Transient heat conduction-lumped heat capacity method. Critical radius of insulation.

Module – II

Elementary ideas of hydrodynamics and thermal boundary layers-Thickness of Boundary layer-Displacement, Momentum and Energy thickness (description only).

Convection heat transfer: Newton's law of cooling- Laminar and Turbulent flow, Reynold's Number, Critical Reynold's Number, Prandtl Number, Nusselt Number, Grashoff's Number and Rayleigh's Number. Dimensional analysis Buckingham's Pi theorem- Application of dimensional analysis to free and forced convection- empirical relations- problems using empirical relations.

Module – III

Combined conduction and convection heat transfer-Overall heat transfer coefficient - Heat exchangers: Types of heat exchangers, AMTD, Fouling factor, Analysis of Heat exchangers- LMTD method, Correction factor, Effectiveness- NTU method, Special type of heat exchangers (condenser and evaporator, simple problems only)

Fins: Types of fins - Heat transfer from fins of uniform cross sectional area- Fin efficiency and effectiveness. Boiling and condensation heat transfer (elementary ideas only).

Introduction to heat pipe.

Module – IV

Radiation- Nature of thermal radiation-definitions and concepts- monochromatic and total emissive power-Intensity of radiation- solid angle- absorptivity, reflectivity and transmissivity-Concept of black body- Planck' law- Kirchoff's law- Wein's displacement law- Stefan Boltzmann's law- black, gray and real surfaces-Configuration factor (derivation for simple geometries only)- Electrical analogy- Heat exchange between black/gray surfaces- infinite parallel plates, equal and parallel opposite plates-perpendicular rectangles having common edge- parallel discs (simple problems using charts and tables). Radiation shields (no derivation).

Mass Transfer :Mass transfer by molecular diffusion- Fick's law of diffusion- diffusion coefficient Steady state diffusion of gases and liquids through solid- equimolar diffusion, Isothermal evaporation of water through air- simple problems.

Convective mass transfer- Evaluation of mass transfer coefficient- empirical relations- simple problems- analogy between heat and mass transfer.

Data book: *Heat and Mass Transfer Data Book*: Kothandaraman C.P. and S. Subramanya, New age International Publishers.

References:

1. Yunus A. Cengel, *Heat Transfer: A Practical Approach*, Tata McGraw Hill Inc., 2003.
2. Holman .J P., *Heat Transfer*, McGraw Hill Inc., New York, 2007.
3. Incropera F. P. and D. P. Dewitt, *Heat and Mass Transfer*. John Wiley and sons, 2006.
4. Rajput R. K., *Heat and Mass Transfer*, S.Chand & Co, 2014.
5. Kothandaraman C. P., *Fundamentals of Heat and Mass Transfer*, Second Edition, New Age International Publishers, 2010.
6. Sachdeva R. C., *Fundamentals of Engineering Heat and Mass Transfer*, New Age Science Limited, 2009.
7. Nag P. K., *Heat and Mass Transfer*, Tata McGraw Hill Publishing Company, 2002.
8. Venketashan S.P., *Heat Transfer*, Ane books, 2011.

Internal Continuous Assessment *(Maximum Marks-50)*

50% - Tests (minimum 2)

30% - Assignments (minimum 2) such as home work, problem solving, quiz, literature survey, seminar, term-project etc.

20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours Maximum Total Marks: 100

The question paper shall consist of 2 parts.

Part A (20 marks) - Ten Short answer questions of 2 marks each. All questions are compulsory. There should be at least two questions from each module and not more than three questions from any module.

Part B (80 Marks) - Candidates have to answer one full question out of the two from each module. Each question carries 20 marks.

Note: *Use of approved data book is permitted in the examination hall.*

Course Outcome:

After successful completion of the course, the student will be able to:

- *understand the basic laws of heat transfer.*
- *apply principles of heat and mass transfer to basic engineering systems*
- *demonstrate general knowledge of heat transfer [conduction, convection, radiation], and general knowledge of mass transfer [molecular diffusion, convection].*
- *analyse the performance and design of heat exchangers.*
- *design heat and mass transfer processes and equipment.*

13.605 CONTROL SYSTEMS (S)

Teaching Scheme: 3(L) - 1(T) - 0(P) **Credits**: 4

Course Objective:

To develop an understanding of feedback control systems and the parameters that influence their stability and performance.

Module – I

Introduction to AFCS: Historical review - control systems applications in aircrafts, missiles, spacecrafts – aircraft flight control systems-models representations – open loop and closed loop -effects of feedback – Transfer function-- Block diagram representation of control systems, Reduction of block diagrams, Signal flow graph representations with applications and problems in aircraft control, systems.

Module – II

Model representations: Mathematical models of physical systems - Simple pneumatic, hydraulic and thermal systems-Mechanical-Electrical systems – Analogies introduction to state space –concept of state variables and state models and derivation of state models from block diagram with reference to aircraft models.

Module – III

Time response and steady state errors: Response of systems to different inputs viz., Step input, impulse, ramp, parabolic and sinusoidal inputs, Time response of first and second order systems, steady state errors and error constants of unity feedback circuit. Automatic controls systems – Controllers - P, PI, PID controllers in aircraft FCS.

Module – IV

Concept of stability & root locus techniques: Characteristic equation, location of roots in S-plane, Concept of stability -Routh - Hurwitz criteria of stability -relative stability, Nyquist stability Criterion, Root locus Techniques – construction of root loci, problems in AFCS domain

Frequency response & applications: Frequency response of the systems – correlation between time and frequency response – gain and phase margins – bode plot method, Applications & problems in Aircrafts Flight control systems.

References:

1. Katsuhiko Ogata, *Modern Control Engineering*, Pearson, New Delhi, 2010.
2. Pallet E. H. J., *Automatic Flight Control*, Shroff Publishers, India, 2004.

3. Gene F. Franklin, J. D. Powell and E. Abbas, *Feedback Control of Dynamic Systems*, 6th edition, Pearson, 2009.
4. Benjamin C. Kuo and Farid Golnaraghi, *Automatic Control Systems*, Volume 1, 8th Ed, John Wiley & Sons, 2003
5. Norman S. Nise, *Control Systems Engineering*,4th edition, John Wiley, New Delhi,2004
6. Richard C. Dorf and Robert H. Bishop, *Modern Control Systems*, 11th edition, Prentice Hall India, 2008
7. Rao V. Dukkipati, *Analysis and Design of Control Systems Using MATLAB*, New Age International Publishers, India, 2006.
8. Brian D.H and D. T. Valentine, *Essential MATLAB for Engineers and Scientists*, 4th ed, Butterworth Heinemann, 2009
9. Roger Pratt, *Flight Control Systems*, Institution of Electrical Engineers, United Kingdom, UK, 2000.

Internal Continuous Assessment *(Maximum Marks-50)*

50% - Tests (minimum 2)

30% - Assignments (minimum 2) such as home work, problem solving, quiz, literature survey, seminar, term-project, software exercises, etc.

20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours *Maximum Total Marks: 100*

The question paper shall consist of 2 parts.

Part A (20 marks) - Ten Short answer questions of 2 marks each. All questions are compulsory. There should be at least two questions from each module and not more than three questions from any module.

Part B (80 Marks) - Candidates have to answer one full question out of the two from each module. Each question carries 20 marks.

Course Outcome:

After this programme students are expected to have

- *Ability to understand low order linear mathematical models of physical systems and their manipulation.*
- *Knowledge on how negative feedback affects dynamic response and its characterization by primary analysis and performance measures.*
- *Knowledge on fundamental mathematical tools used in system analysis and design.*

13.606.1 HIGH SPEED AERODYNAMICS (S) (Elective II)

Teaching Scheme: 3(L) - 1(T) - 0(P) **Credits**: 4

Course Objectives:

To introduce students the basic concepts in the field of high speed aerodynamics. Transonic and supersonic flow problems. External flows (supersonic airfoils, wings and aircraft in general) and experimental methods

Module – I

Concepts of compressible flow: Introduction to isentropic flow-Scope of compressible flow-Review of continuity, momentum and steady flow energy equations and entropy considerations- Energy and momentum equations for compressible fluid flow reference velocities-stagnation states-velocity of sound-critical states-mach number-critical Mach number. Types of waves- mach cones, mach angle-effect of Mach number on compressibility flow regimes.

Module – II

Shocks and expansion waves: Development of normal shocks-governing equations-Stationery and moving normal shock waves-applications, applications to supersonic wind tunnel. Shock tubes, Shock polars, supersonic pitot probes. Oblique shock – Reflection of flow- Prantl- Meyer expansion flow. Under and over expanded nozzles, shock expansion method for flow over airfoils.

Module – III

Flow in constant area duct with friction and heat transfer: Fanno flow and Rayleigh flow - flow tables and charts for Fanno flow and Rayleigh flow.

Module – IV

Brief introduction to the methods of characteristics: Method of characteristics – Prandtl - Glauert and Goethert rules - Ackeret's supersonic airfoil theory. Small perturbation equations for subsonic, transonic, supersonic and hypersonic flow. Experimental characteristics of Airfoils in compressible flow.

Experimental methods: Transonic, Supersonic and hypersonic wind tunnels and characteristic features, their operation and performance-Flow visualization methods of supersonic flows.

References

1. Radhakrishnan and Ethirajan., *Gas Dynamics*, John Wiley & Sons,2010.

2. Yahya, S. M., *Fundamentals of Compressible flow with Aircraft and Rocket Propulsion*, 3rd edition, New Age International Ltd. Publishers, 2003.
3. Shapiro, Ascher. H., The *Dynamics and Thermodynamics of Compressible Fluid Flow (Vol I and II),* Ronald Press, 1953.
4. Anderson J. D., Jr., *Modern Compressible Flow with Historical Perspective*, McGraw Hill Publishing Co., 2004.
5. Edward R. C. Miles, *Supersonic Aerodynamics*, Dover, New York, 1950.
6. Clancy, L. J., *Aerodynamics,* Pitman, 1986.
7. Anderson J. D., Jr., *Fundamentals to Aerodynamics*, McGraw Hill Publishing Co., 3rd edition, 2001.

Internal Continuous Assessment *(Maximum Marks-50)*

50% - Tests (minimum 2)

30% - Assignments (minimum 2) such as home work, problem solving, literature survey, seminar, term-project, software exercises, etc.

20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours *Maximum Total Marks: 100*

The question paper shall consist of 2 parts.

Part A (20 marks) - Ten Short answer questions of 2 marks each. All questions are compulsory. There should be at least two questions from each module and not more than three questions from any module.

Part B (80 Marks) - Candidates have to answer one full question out of the two from each module. Each question carries 20 marks.

Course outcome:

Upon completion the student understands the basic concepts and problems addressed in the field of aerodynamics at transonic and supersonic speeds.

13.606.2 WIND TUNNEL TECHNOLOGY (S) (Elective II)

Teaching Scheme: 3(L) - 1(T) - 0(P) **Credits**: 4

Course Objectives:

The students are exposed to various types and techniques of Aerodynamic data generation on aerospace vehicle configurations in the aerospace industry.

Module – I

Principles of model testing: Buckingham Theorem – Non dimensional numbers – Scale effect – Geometric Kinematic and Dynamic similarities.

Module – II

Types and functions of wind tunnels: Classification and types – special problems of testing in subsonic, transonic, supersonic and hypersonic speed regions – Layouts – sizing and design parameters.

Module – III

Calibration of wind tunnels: Test section speed – Horizontal buoyancy – Flow angularities – Flow uniformity & turbulence measurements – Associated instrumentation – Calibration of subsonic & supersonic tunnels.

Module – IV

Conventional measurement methods: Force measurements and measuring systems – Multi component internal and external balances –Pressure measurement system - Steady and Unsteady Pressure- single and multiple measurements- Velocity measurements – Intrusive and Non-intrusive methods – Flow visualization techniques surface flow, oil and tuft - flow field visualization, smoke and other optical and nonintrusive techniques

Special wind tunnel techniques: Intake tests – store carriage and separation tests - Unsteady force and pressure measurements –wind tunnel model design.

References

1. Rae, W.H. and Pope, A., *Low Speed Wind Tunnel Testing*, John Wiley Publication, 1984.
2. NAL-UNI Lecture Series 12: *Experimental Aerodynamics*, NAL SP 98 01 April 1998.
3. Pope A., and L. Goin, *High Speed Wind Tunnel Testing*, John Wiley, 1985.
4. Bradsaw, Experimental Fluid Mechanics.
5. Short term course on *Flow Visualization Techniques*, NAL , 2009

6. Lecture course on *Advanced Flow Diagnostic Techniques* 17-19 September 2008 NAL, Bangalore

Internal Continuous Assessment *(Maximum Marks-50)*

50% - Tests (minimum 2)

30% - Assignments (minimum 2) such as home work, problem solving, literature survey, seminar, term-project, software exercises, etc.

20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours Maximum Total Marks: 100

The question paper shall consist of 2 parts.

Part A (20 marks) - Ten Short answer questions of 2 marks each. All questions are compulsory. There should be at least two questions from each module and not more than three questions from any module.

Part B (80 Marks) - Candidates have to answer one full question out of the two from each module. Each question carries 20 marks.

Course outcome:

At the end of this course the students will be able to use various techniques of Aerodynamic data generation.

13.606.3 FINITE ELEMENT METHOD (S) (Elective II)

Teaching Scheme: 3(L) - 1(T) - 0(P) **Credits**: 4

Course Objectives:

- *To acquaint with basic concepts of finite element formulation methods.*
- *To practice finite element methodologies through simple structural and heat transfer problems.*

Module – I

Introduction: Finite element method as a numerical tool for design – basic concepts – formulation procedures – historical development – current trends – free and commercial FE packages.

FE modeling Direct approach: 1-D bar element – element stiffness – assembly of elements – properties of [K] matrix – treatment of boundary conditions – temperature effects – stress computation – support reaction – simple problems. Analogous (1-D) problems of torsion, heat conduction and laminar pipe flow.

Beam element: Beam relationships – 1-D beam element FE formulation - element stiffness matrix – load considerations – boundary conditions – member end forces.

Module – II

FE modeling Direct approach : Plane truss element formulation – coordinate transformation – local and global coordinates – element matrices – assembly of elements – treatment of boundary conditions – stress calculation – simple problems - band width of the stiffness matrix – node numbering to exploit matrix sparsity – conservation of computer memory.

Interpolation – shape function – Lagrange interpolation - 1D linear and quadratic, 2D linear triangle and bilinear rectangular elements.

FE formulation from virtual work principle – B-matrix – element matrices for bar and CST elements – load considerations – consistent nodal loads – simple problems.

Module – III

Variational methods : – Functionals – weak and strong form – essential and non- essential boundary conditions - Principle of stationary potential energy – Rayleigh-Ritz method – simple examples.

FE formulation from a functional: 2-D steady state heat conduction – element matrices for a triangular element – boundary conditions – simple problems. FE formulation for 2-D stress analysis from potential energy - element matrices - plane bilinear element.

Convergence requirements – patch test – modeling aspects – symmetry – element size and shape – sources of error.

Module – IV

Weighted residual methods: Galerkin FE formulation – axially loaded bar – heat flow in a bar.

Isoparametric formulation: Natural coordinates – linear and quadratic bar element – linear triangle and plane bilinear elements for scalar fields – jacobian matrix – element matrices - Gauss quadrature – requirements for isoparametric elements – accuracy and mesh distortion.

References

1. Chandrupatla T. R. and A. D. Belegundu, *Introduction to Finite Elements in Engineering*, 2nd Edition, Prentice Hall, New Jersey, 1997.
2. Daryl L. Logan, *A First Course in the Finite Element Method*, 2nd Edition, PWS Publishing Company, Boston, 1993.
3. Rao S. S., *The Finite Element Method In Engineering*, Pergamon Press, 1989
4. Huebner K. H., D. L. Dewhirst, D. E. Smith and T. G. Byron, *The Finite Element Method for Engineers*, 4th Edition, John Wiley & Sons Inc., New York, 2001.
5. Reddy J. N., *An Introduction to the Finite Element Method*, 2nd Edition, McGraw-Hill,Inc., New York, 1993.
6. . Robert C. D., M. S. David and P. E. Michel, *Concepts and Applications of Finite Element Analysis*, John Wilely & Sons, 3rd Ed., New York, 2000.
7. Hutton D. V., *Fundamentals of Finite Element Analysis*, Tata McGraw Hill.
8. Bhavakatti S. S., *Finite Element Analysis,* New Age International.
9. Bathe K. J., *Finite Element Procedures in Engineering Analysis,* Prentice Hall of India.
10. Zienkiewics O. C.and R. L. Taylor, *The Finite Element Method,* Vol I & II, McGraw Hill.

Internal Continuous Assessment *(Maximum Marks-50)*

50% - Tests (minimum 2)

30% - Assignments (minimum 2) such as home work, problem solving, literature survey, seminar, term-project, software exercises, etc.

20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours *Maximum Total Marks: 100*

The question paper shall consist of 2 parts.

Part A (20 marks) - Ten Short answer questions of 2 marks each. All questions are compulsory. There should be at least two questions from each module and not more than three questions from any module.

Part B (80 Marks) - Candidates have to answer one full question out of the two from each module. Each question carries 20 marks.

Course outcome:

At the end of this course, students will know the mathematical formulation of the finite element method and how to apply it to basic (linear) ordinary and partial differential equations. Students will also learn how to implement the finite element method efficiently in order to solve a particular equation.

13.606.4 HELICOPTER AERODYNAMICS (S) (Elective II)

Teaching Scheme: 3(L) - 1(T) - 0(P) **Credits**: 4

Course Objectives:

To understand and acquire a good understanding on vertical flight vehicles, its principles, aerodynamics, performance and basic design aspects of helicopter.

Module – I

Quality Introduction and elements of helicopter aerodynamics: Brief History of Helicopters- Early Years, first word war era, Inter-war years, second world war era, Post world war Years. The Helicopter from an Engineering viewpoint. Configurations based on torque reaction-Jet rotors and compound helicopters- Methods of control – Collective and cyclic pitches changes - Lead - Lag and flapping hinges, lift dissymmetry, Helicopters contra rotating, tandem and tail rotor configuration and their advantages and disadvantages. Auto rotation of helicopter. Rotor wake model, Ground effect on lifting rotors.

Module – II

Quality Rotor in vertical flight: momentum theory and wake analysis: Momentum theory for hover, Non-dimensionalization, Figure of Merit, Axial Flight, Momentum theory of Vertical climb, Modeling the stream tube, Descent, Wind tunnel Test Results, Complete Induced Velocity curve.

Blade Element Theory: Basic Method, Thrust Approximation, Non Uniform Flow, Ideal Twist, Blade Mean lift Coefficient, Power Approximations, Tip Loss,(All topics in Hovering condition) Examples of Hover Characteristics.

Module – III

Rotor in forward flight: rotor mechanism: The Edgewise rotor, Flapping Motion, Rotor Control, Equivalence of Flapping and Feathering (Blade Sailing, Lagging motion, Coriolis Acceleration, Lag frequency, Blade Flexibility, Ground Resonance).

Rotor aerodynamics : Momentum Theory, Descending Forward Flight, Wake Analysis, Blade Element Theory (Factors involved, Thrust, In- Plane H – Force, Torque and power, Flapping Coefficients).

Module – IV

Rotor aerodynamic design: Blade Section design, Blade Tip Shapes (Rectangular, Swept, Advance Planforms), Tail Rotors (Propeller Moment, Precession-Yaw Agility, Calculation of Downwash, Yaw Acceleration), Parasite Drag, Rear Fuselage Upsweep, Aerodynamic Design process.

References

1. Gessow, A., and Myers, G.C. *Aerodynamics of Helicopter*, Macmillan & Co., N.Y.1987.
2. McCormick, B.W., Aerodynamics of V/STOL Flight, Academics Press, 1987.
3. John Fay, "The Helicopter and How It Flies", Himalayan Books 1995.
4. Lalit Gupta, "Helicopter Engineering", Himalayan Books New Delhi 1996.
5. Joseph Schafer, "Basic Helicopter Maintenance", Jeppesen, 1980.
6. Prouty R W, "Helicopter Aerodynamics"
7. John Seddon and Simon Newman, *Basic Helicopter Aerodynamics,* III rd Edition, John Wiley & Sons Ltd., U.K.
8. Johnson, W. Princeton, *Helicopter Theory,* University Press, 1980.

Internal Continuous Assessment *(Maximum Marks-50)*

50% - Tests (minimum 2)

30% - Assignments (minimum 2) such as home work, problem solving, literature survey, seminar, term-project, software exercises, etc.

20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours *Maximum Total Marks: 100*

The question paper shall consist of 2 parts.

Part A (20 marks) - Ten Short answer questions of 2 marks each. All questions are compulsory. There should be at least two questions from each module and not more than three questions from any module.

Part B (80 Marks) - Candidates have to answer one full question out of the two from each module. Each question carries 20 marks.

Course outcome:

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

- *To perform the Aerodynamics calculation of Rotor blade*
- *To perform stability and control characteristics of Helicopter*
- *To perform and control Rotor vibration*

13.606.5 CONTROL NAVIGATION AND GUIDANCE (S) (Elective II)

Teaching Scheme: 3(L) - 1(T) - 0(P) **Credits**: 4

Course Objectives:

- *To introduce the basic concepts of navigation & guidance systems of aircraft.*
- *To develop an understanding of the principles of aircraft motion measurement and control and sensors and actuator for aircraft control and guidance.*

Module – I

Inertial sensors: Gyroscopes-Mechanical-electromechanical-Ring Laser gyro- Fiber optic gyro, Spinning rotor gyro-principle of operation, single degree of freedom rate gyro – two axis gyro- dynamically tuned gyro- coriolis vibratory gyros- Accelerometers.

Inertial Navigation Systems: INS components: transfer function and errors-The earth in inertial space, the coriolis effect-Mechanisation. Platform and Strap down, INS system block diagram, Different co-ordinate systems, Schuler loop, compensation errors, Gimbal lock, Alignment.

Module – II

Radio navigation: Different types of radio navigation- ADF, VOR/DME- Doppler –LORAN, DECCA and Omega – TACAN.

Module – III

Approach and landing aids: ILS, MLS, GLS - Ground controlled approach system - surveillance systems-radio altimeter, RNAV, Modern Navigation Aids.

Module – IV

Satellite Navigation & Hybrid Navigation: Introduction to GPS -system description -basic principles -position and velocity determination-signal Structure- DGPS, Introduction to Kalman filtering-Estimation and mixed mode navigation-Integration of GPS and INS-utilization of navigation systems in aircraft

References

1. Myron Kyton and Walfred Fried, *Avionics Navigation Systems*, John Wiley & Sons,2nd edition, 1997.
2. Nagaraja N. S. *Elements of Electronic Navigation*, Tata McGraw-Hill Pub. Co., New Delhi, 2nd edition, 1975.
3. George M. Siouris, *Aerospace Avionics System; A Modern Synthesis*, Academic Press Inc., 1993.

4. Albert Helfrick, *Practical Aircraft Electronic Systems*, Prentice Hall Education, Career & Technology, 1995.
5. Albert D. Helfrick, *Modern Aviation Electronics*, Second Edition, Prentice Hall Career & Technology, 1994.
6. Sen, A. K. and A. B. Bhattacharya, *Radar System and Radar Aids to Navigation*, Khanna Publishers, 1988.
7. Slater, J. M. Donnel, C. F. O and others, *Inertial Navigation Analysis and Design*, McGraw-Hill Book Company, New York, 1964.
8. Bose A., K. N. Bhat and Thomas Kurian, *Fundamentals of Navigation and Inertial Sensors*, PHI Learning Pvt Ltd, 2014.

Internal Continuous Assessment *(Maximum Marks-50)*

50% - Tests (minimum 2)

30% - Assignments (minimum 2) such as home work, problem solving, literature survey, seminar, term-project, software exercises, etc.

20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours *Maximum Total Marks: 100*

The question paper shall consist of 2 parts.

Part A (20 marks) - Ten Short answer questions of 2 marks each. All questions are compulsory. There should be at least two questions from each module and not more than three questions from any module.

Part B (80 Marks) - Candidates have to answer one full question out of the two from each module. Each question carries 20 marks.

Course outcome:

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

- *Understand flight dynamics and select the appropriate avionics sensor to measure the corresponding motion variable;*
- *Analyze the functional structure of avionics systems within a modern aircraft and to define the performance of a component sub-system.*

13.606.6 ADVANCED MECHANICS OF SOLIDS (S) (Elective II)

Teaching Scheme: 3(L) - 1(T) - 0(P) **Credits**: 4

Course Objectives:

- *To impart concepts of stress and strain analysis in a solid.*
- *To study the methodologies in theory of elasticity at a basic level.*
- *To acquaint with energy methods to solve structural problems.*

Module – I

Basic equations of elasticity: Stress at a point with respect to a plane – normal and tangential components of stress – stress tensor – Cauchy's equations – stress transformation – principal stresses and planes – strain at a point - strain tensor – analogy between stress and strain tensors – constitutive equations – generalized Hooke's law – relation among elastic constants – equations of equilibrium – strain-displacement relations – compatibility conditions – boundary conditions – Saint Venant's principle for end effects – uniqueness condition.

Module – II

2-D problems in elasticity: Plane stress and plane strain problems – Airy's stress function – solutions by polynomial method – solutions for bending of a cantilever with an end load, and bending of a beam under uniform load. Equations in polar coordinates – Lame's problem - stress concentration problem of a small hole in a large plate. Axisymmetric problems – thick cylinders – interference fit – rotating discs.

Module – III

Special problems in bending: Unsymmetrical bending – shear center – curved beams with circular and rectangular cross-section.

Energy methods in elasticity: Strain energy of deformation – special cases of a body subjected to concentrated loads, due to axial force, shear force, bending moment and torque – reciprocal relation – Maxwell reciprocal theorem – Castigliano's first and second theorems – virtual work principle – minimum potential energy theorem - complementary energy.

Module – IV

Torsion of non-circular bars: Saint Venant's theory - Prandtle's method - solutions for circular and elliptical cross-sections - membrane analogy - torsion of thin walled open and closed sections – shear flow.

References

1. Sreenath L. S., *Advanced Mechanics of Solids*, McGraw Hill.

2. Kazimi S. M. A., *Solid Mechanics*, McGraw Hill.
3. Timoshenko S. P. and J. N. Goodier, *Theory of Elasticity,* McGraw Hill.
4. Den Hartog J. P., *Advance Strength of Materials*, McGraw Hill.
5. Wang C. K., *Applied Elasticity*, McGraw Hill.

Internal Continuous Assessment *(Maximum Marks-50)*

50% - Tests (minimum 2)

30% - Assignments (minimum 2) such as home work, problem solving, literature survey, seminar, term-project, software exercises, etc.

20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours *Maximum Total Marks: 100*

The question paper shall consist of 2 parts.

Part A (20 marks) - Ten Short answer questions of 2 marks each. All questions are compulsory. There should be at least two questions from each module and not more than three questions from any module.

Part B (80 Marks) - Candidates have to answer one full question out of the two from each module. Each question carries 20 marks.

Course outcome:

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

- *Understand advanced stress/strain correlations.*
- *Obtain simple mathematical and physical relationships between mechanics and materials.*
- *Model the plastic behaviour, as well as the fatigue, fracture and creep response, of common engineering materials.*
- *Establish links between theoretical and practical applications; identify problems and formulate solution strategies.*

13.607 LOW SPEED AERODYNAMICS LAB (S)

Teaching Scheme: 0(L) - 0(T) - 3(P) **Credits**: 3

Course Objective:

To study experimentally the aerodynamic forces on different bodies at all flow regimes.

List of Experiments:

1. Study of the pressure distribution over smooth and rough cylinder.
2. Study of the Pressure distribution over symmetric airfoil.
3. Study of the Pressure distribution over cambered airfoil & thin airfoils
4. Study of the characteristics of three dimensional airfoils involving measurement of lift, drag, pitching moment.
5. Calibration of subsonic wind tunnel.
6. Pressure distribution over smooth and rough cylinder.
7. Pressure distribution over symmetric airfoils.
8. Pressure distribution over cambered airfoils & thin airfoils
9. Flow visualization studies in low speed flows over cylinders
10. Flow visualization studies in low speed flow over airfoil with different angle of Incidence
11. Boundary layer investigation on a flat plate zero, favourable and adverse pressure gradient flow.
12. Force measurements using wind tunnel balances
13. Drag estimation using wake survey.
14. Performance of an aerofoil with flap, influence of flap angle on lift, drag and stall.
15. Calibration of angle of attack vs. lift coefficient of an aerofoil.

Note : At least 10 experiments from the above list shall be conducted.

Internal Continuous Assessment *(Maximum Marks-50)*

40% - Test
40% - Class work and Record
20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours *Maximum Total Marks: 100*

Questions based on the list of experiments prescribed.

80% - Procedure, conducting experiment, results, tabulation and inference

20% - Viva voce

Candidate shall submit the certified fair record for endorsement by the external examiner.

Course Outcome:

Students will get an insight into the use of different experimental techniques used to assess the aerodynamic forces on different bodies.

13.608 FLUID & FLIGHT MECHANICS LAB (S)

Teaching Scheme: 0(L) - 0(T) - 3(P) **Credits**: 3

Course Objective:

To experimentally study the principles of fluid and flight mechanics.

List of Experiments:

1. Determinations of flow throw pipes, Losses in pipes.
2. Calibration of Orifice meter and Venturi meter.
3. Flow through notches and weir
4. Flow through open Orifice -Cd, Cc and Cv
5. Buoyancy experiment -Meta Centric height
6. Study and experiment on Bernoulli's theorem apparatus.
7. Study and experiment on Reynolds apparatus.
8. Flight Simulator Computer Equipment
9. Aero-modeling Flight Simulator
10. Study of aero-modeling Equipments and tools
11. Determination of phugoid motion in terms of altitude.
12. Practical investigation on rate of climb and turn radius
13. Systematic study of CG location variation in any trainer aircraft.

Note : At least 10 experiments from the above list shall be conducted.

Internal Continuous Assessment *(Maximum Marks-50)*

40% - Test
40% - Class work and Record
20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours *Maximum Total Marks: 100*

Questions based on the list of experiments prescribed.

80% - Procedure, conducting experiment, results, tabulation and inference

20% - Viva voce

Candidate shall submit the certified fair record for endorsement by the external examiner.

Course Outcome:

At the end of the course, the students will be familiar with the various experimental techniques to study the principles of fluid and flight mechanics and its effect on of aircrafts.