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IV Year B.Tech. AE-I Sem	L	T/P/D	C
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(A72118) AIRFRAME STRUCTURAL DESIGN

Objective:

To introduce to the student, the basic concepts, specification of design requirements and methodology of Aircraft Structural Design.

UNIT-I

Introduction and Airworthiness Requirements: Structural design and sizing stages, Principal structural components of aircraft Design requirements- structural integrity, stiffness, service life, Constraints- baseline aerodynamic configuration, external loading, weight, operating conditions, conformity to government regulations. Design for durability, damage tolerance.

Airworthiness requirements - loads, safety margins, material properties, methods of estimation- construction, operation, maintenance, training-procedures. Critical load conditions. Limit and ultimate loads- definition, significance. Aircraft materials- mechanical properties- design data-allowable, allowable bases. Failure theory. Flight loads- atmospheric, maneuver- construction of flight envelope.

UNIT-II

External Loads – Estimation, Fasteners and Structural Joints: Wing loads- air load span wise distribution, effect of fuselage, engine nacelle, wing stores, control surfaces, landing, taxi, dynamic gust loads, wing weight distribution. Empennage loads- gust, maneuver, control surface. Fuselage loads- distribution of weight, fore body loads, after body loads, internal pressure, propulsion loads. Landing gear loads- landing conditions, ground handling loads, retraction loads- Miscellaneous loads. Airplane weight data, stiffness data. Theories of Failure.

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Fasteners and fittings- role, significance, general design considerations, criteria for allowable strength. Margins of safety. Fastener systems, types, fastener information, dimensions, material, allowable strength- tensile, shear, bending, bearing, Rivets, bolts and screws, nuts- detail design considerations. Fastener selection. Fittings- lugs, bushings and bearings- loading, design and analysis. Joints- spliced, eccentric, gusset, welded, brazed, bonded-types, methods of joining, failure modes. Fatigue design considerations. Stress concentration- causes, methods of reduction. Fastener load distribution and by-pass load- severity factor, structural joint life prediction. Shim control and requirement.

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UNIT- III

Design of Wing, Tail Unit Structures : The wing- role- summary of wing loads, structural components- wing box, leading and trailing edges. Wing layout- location of spars, ailerons and flaps, rib spacing and direction, root rib bulkhead, span wise stiffeners, wing covers- skin-stringer panels, integrally stiffened panels, access holes, and attachment of leading edge and trailing edge panels. Spars- general rules of spar design. Ribs and bulkheads- rib spacing and arrangement. Wing root joints, carry through structure. Fighter wing design- problems with swept wings

Wing box, root rib bulkhead- estimation of loads, stress analysis, design parameters, optimisation, sizing, margins of safety. Leading and trailing edge assembly- control surfaces, flaps- structure.

UNIT-IV

Design of Fuselage, Landing Gear, Engine Mounts : Function of fuselage-loading, general requirements. Ultimate strength of stiffened cylindrical structure- review, Principal structural components- skin and stringers, frame and floor beam, pressure bulkhead, wing and fuselage intersection- lay out, loading, stress analysis, sizing. Forward fuselage, aft fuselage structures, fuselage openings- windows, doors- design considerations.

Landing gear- purpose, types, general arrangement, loads- design considerations- ground handling, take-off, landing, braking, pavement loading, support structure. Stowage and retraction, gear lock- kinematic design. Shock absorbers- function, types, components, operation, loads, materials, design. Wheels and brakes, tire selection Engine mounts- types-wing pod, rear fuselage, tail, fuselage mount, loads, design considerations.

UNIT- V

Fatigue Life, Damage Tolerance, Fail-Safe Design- Weight Control and Balance: Catastrophic effects of fatigue failure- examples- modes of failure-design criteria- fatigue stress, fatigue performance, fatigue life. Fatigue design philosophy- fail-safe, safe life. Service behaviour of aircraft structures- effect of physical and load environment design and of detail of fabrication Structural life- methods of estimation- the scatter factor- significance Fail-safe design-the concept, requirements, damage tolerance- estimation of fatigue strength

TEXT BOOKS

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1. Niu, M.C., Airframe Structural Design, second edition, Hongkong Conmlit Press, 1988, ISBN: 962-7128- 09-0.

2. Niu, M.C., Airframe Stress Analysis and Sizing, second edition, Hongkong Conmlit Press, 1997, ISBN: 962-7128-08-2.

REFERENCES

1. Bruhn, E.H., Analysis and Design of Flight Vehicles Structures, Tri - state Offset Company, USA, 1965.
2. Peery, D.J, and Azar, J.J., Aircraft Structures, second edition, Mc Graw-Hill, N.Y., 1993.
3. Megson, T.H.G., Aircraft Structures for Engineering Students, Butterworth-Heinemann/ Elsevier, 2007.
4. Raymer, D.P., *Aircraft Design: A Conceptual Approach*, 3rd edn., AIAA Education Series, AIAA, 1999, ISBN: 1-56347- 281-0.
5. Fielding, J.P., Introduction to Aircraft Design, Cambridge University Press, 2005, ISBN: 0-521-657222-9.

Outcome: The student should be able to estimate the major loads on the principal structural components of the aircraft, prepare the layout, determine the principal design parameters of the components, conduct stress analysis of the structural elements and prepare the necessary drawings and reports..

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(A72122) MECHANICAL VIBRATION AND STRUCTURAL DYNAMICS

Objectives: The course provides essential background on Structural Dynamics require for Aeronautical Engineers. The course will help students to solve many practical engineering problems using the techniques developed in this course. With knowledge in finite element method one can solve more complex structural dynamics problem using general purpose FE codes. The course will also provide foundation for advance course in structural dynamics and aeroelasticity.

UNIT – I

Free Vibration of Single-Degree-Of-Freedom-System: Importance of the Study of Vibration; Basic Concepts of Vibration - Elementary Parts of Vibrating Systems, Number of Degrees of Freedom, Discrete and Continuous Systems; Classification of Vibration - Free and Forced Vibration, Undamped and Damped Vibration, Linear and Nonlinear Vibration, Deterministic and Random Vibration; Vibration Analysis Procedure, Spring Elements, Mass or Inertia Elements, Damping Elements, Harmonic Motion, Harmonic Analysis.

Introduction, Free Vibration of an Undamped Translational System, Free Vibration of an Undamped Torsional System, Response of First Order Systems and Time Constant, Rayleigh s Energy Method, Free Vibration with Viscous Damping, Graphical Representation of Characteristic Roots and Corresponding Solutions, Parameter Variations and Root Locus Representations, Free Vibration with Coulomb Damping, Free Vibration with Hysteretic Damping, Stability of Systems

UNIT - II

Vibration Under Harmonic Forcing Conditions: Introduction, Equation of Motion, Response of an Undamped System Under Harmonic Force, Response of a Damped System Under Harmonic Force, Response of a Damped System Under $F(t)=F_0e^{i\omega t}$, Response of a Damped System Under the Harmonic Motion of the Base, Response of a Damped System Under Rotating Unbalance, Forced Vibration with Coulomb Damping, Forced Vibration with Hysteresis Damping, Forced Motion with Other Types of Damping, Self-Excitation and Stability Analysis, Transfer-Function Approach.

UNIT - III

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Vibration Under General Forcing Conditions: Introduction, Response Under a General Periodic Force, Response Under a Periodic Force of Irregular Form, Response Under a Nonperiodic Force, Convolution Integral, Response Spectrum, Laplace Transform, Numerical Methods, Response to

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Irregular Forcing Conditions Using Numerical Methods

UNIT - IV

Two-Degree- and Multi-Degree-of-Freedom Systems: Introduction, Equations of Motion for Forced Vibration, Free Vibration Analysis of an Undamped System, Torsional System, Coordinate Coupling and Principal Coordinates, Forced-Vibration Analysis, Semi-definite Systems, Self-Excitation and Stability Analysis

Modeling of Continuous Systems as Multi-degree-of-Freedom Systems, Using Newton s Second Law to Derive Equations of Motion, Influence Coefficients - Stiffness Influence Coefficients, Flexibility influence Coefficients, Inertia Influence Coefficients; Potential and Kinetic Energy Expressions in Matrix Form, Generalized Coordinates and Generalized Forces, Using Lagrange s Equations to Derive Equations of Motion, Equations of Motion of Undamped Systems in Matrix Form, Eigenvalue Problem, Solution of the Eigenvalue Problem, Expansion Theorem, Unrestrained Systems, Free Vibration of Undamped Systems, Forced Vibration of Undamped Systems Using Modal Analysis, Forced Vibration of Viscously Damped Systems, Self-Excitation and Stability Analysis

UNIT – V

Continuous Systems: Introduction, Transverse Vibration of a String or Cable, Longitudinal Vibration of a Bar or Rod, Torsional Vibration of a Shaft or Rod, Lateral Vibration of Beams, The Rayleigh-Ritz Method

TEXT BOOKS

1. Rao, S.S., Mechanical Vibrations, Fifth Edition, Prentice-Hall, 2011.
2. Thomson, W.T., Theory of vibrations with applications, CBS Publishers, Delhi.
3. Meirovitch, L., Fundamentals of vibrations, McGraw Hill International Edition, 2001.

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REFERENCES

1. Leissa, A.W., Vibration of continuous system, The McGraw-Hill Company, 2011.
2. Inman, D.J., Vibration Engineering, Third Edition, Prentice Hall Int., Inc., 2001,
3. Kelly, S.G., Schaum's Outline of The Theory and Problems of Mechanical Vibrations, Schaum's Outline Series, McGraw-Hill, 1996.

Outcome: At the end of the course students will be in a position to solve simple vibration problem using techniques described in units I to III. With some knowledge in general purpose software, students will be in a position to solve more complex vibration of flight vehicles.

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(A70328) CAD / CAM

UNIT – I

Fundamentals of CAD/CAM, Automation , design process, Application of computers for design, Benefits of CAD, Computer configuration for CAD applications, Computer peripherals for CAD , Design workstation, Graphic terminal, CAD software- definition of system software and application software ,CAD database and structure.

Geometric Modeling: 3-D wire frame modeling, wire frame entities and their definitions, Interpolation and approximation of curves, Concept of parametric and non-parametric representation of curves, Curve fitting techniques, definitions of cubic spline, Bezier, and B-spline.

UNIT-II

Surface modeling: Algebraic and geometric form, Parametric space of surface, Blending functions, parameterization of surface patch, Subdividing, Cylindrical surface, Ruled surface, Surface of revolution, Spherical surface, Composite surface, Bezier surface. B-spline surface, Regenerative surface and pathological conditions

Solid Modelling: Definition of cell composition and spatial occupancy enumeration, Sweep representation, Constructive solid geometry, Boundary representations.

UNIT – III

NC Control Production Systems: Numerical control, Elements of NC system, NC part programming : Methods of NC part programming, Manual part programming, Computer assisted part programming, Post Processor, Computerized part program, SPPL (A Simple Programming Language). CNC, DNC and Adaptive Control Systems

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UNIT – IV

Group Technology: Part families, Parts classification and coding. Production flow analysis, Machine cell design.

Computer aided process planning: Difficulties in traditional process planning, Computer aided process planning: retrieval type and generative type, Machinability data systems.

Computer aided manufacturing resource planning: Material resource planning, inputs to MRP, MRP output records, Benefits of MRP, Enterprise resource planning, Capacity requirements planning.

UNIT – V

Flexible manufacturing system: F.M.S equipment, FMS layouts, Analysis methods for FMS benefits of FMS.

Computer aided quality control: Automated inspection- Off-line, On-line, contact, Non-contact; Coordinate measuring machines, Machine vision.

Computer Integrated Manufacturing: CIM system, Benefits of CIM, Benefits of CIM

TEXT BOOKS:

1. CAD/CAM /Groover M.P./ Pearson education
2. CAD/CAM Concepts and Applications/ Alavala/ PHI

REFERENCE BOOKS :

1. CAD/CAM Principles and Applications/P.N.Rao/ TMH
2. CAD / CAM Theory and Practice/ Ibrahim Zeid/TMH
3. CAD / CAM / CIM/Radhakrishnan and Subramanian/ New Age
4. Principles of Computer Aided Design and Manufacturing/ Farid Amirouche/ Pearson
5. Computer Numerical Control Concepts and programming/Warren S Seames/ Thomson

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(A72119) CONTROL THEORY- APPLICATION TO FLIGHT CONTROL SYSTEMS

Objectives: *To acquaint the student with methods of modeling, performance analysis, and synthesis of control systems and application to aircraft flight control systems.*

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UNIT- I

Control Systems- Modeling- Feedback Control: Dynamical systems- input, output- process (plant)- block diagram representation. Control input, noise. Function of control as regulation (hold), tracking (command)- examples. Sensitivity of output to control input, noise and to system parameters- robustness. Deterministic and stochastic control. Need for stable, effective (responsive), robust control system. Modeling of dynamical systems by differential equations- system parameters. Order of the system. Single input single output systems, multiple-input-multiple-output systems- linear and nonlinear systems. Linearisation of nonlinear systems. Time invariant linear systems.

The concept of feedback- open loop control, closed loop control. Effect of feedback on input-output relation, stability, robustness. Merits of feedback control. Loop gain, feedback gain- significance. System type, steady state error, error constants- overall system stability. Application of feed back in stability augmentation, control augmentation, automatic control- examples.

Composition, reduction of block diagrams of complex systems- rules and conventions. Control system components- sensors, transducers, servomotors, actuators, filters- modeling, transfer functions. Single-input-single-output systems. Multiple input- multiple output systems, matrix transfer functions- examples.

UNIT- II

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Performance– Time, Frequency and S-Domain Description- : Control system performance- time domain description- output response to control inputs— impulse and indicial response- characteristic parameters - relation to system parameters. Synthesis of response to arbitrary input functions from impulse and indicial response. Review of Laplace transforms- applications to differential equations. 's' domain description of input-output relations- transfer functions- system parameters- gain, poles and zeroes. Partial fraction decomposition of transfer functions- significance. . Dominant poles. Relation of transfer function to impulse response. Frequency domain description- frequency response- gain and phase shift- significance-

asymptotic (Bode) plots, polar (Nyquist) plots, frequency transfer functions. Characteristic parameters- corner frequencies, resonant frequencies, peak gain, bandwidth- significance. First and second order systems- extension to higher order systems.

System identification from input output measurements- importance. Experimental determination of system transfer functions by frequency response measurements. Example.

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UNIT- III

Specification of Control System Performance Requirements- System Synthesis- Controllers- Compensation Techniques : Control system performance requirements- transient and steady state- specification- desired input-output relation- speed of response, stability, accuracy, steady state error, robustness. Relation with system parameters. Examples of first and second order systems. Specifications in time, frequency, and 's' domains. Conflicting requirements- need for compromise- scope for optimisation. The primacy of stability.

System synthesis- need for compensation- design of controllers- active, passive- series, feed forward, feedback controllers. Proportional, integral, proportional plus derivative control- the problem with derivative control - lead, lag, lead-lag, wash-out, notch filters/ networks- properties- effect on transfer function, stability, robustness- relative merits. Adaptive control- definition, merits, implementation- gain scheduling. Non linear control, merits, constraints. Feedback controllers. Significance of loop transfer function, loop gain. Stability of closed loop system- frequency response methods and root locus methods of analysis and compensation- Nyquist's criterion- stability margins- phase margin, gain margin- interpretation, significance- compensation by pole zero cancellation. Design of multi loop feedback systems.

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UNIT- IV

Aircraft Response to Controls- Flying Qualities- Stability and Control Augmentation- Autopilots: Approximations to aircraft transfer functions, control surface actuators- review. Response of aircraft to pilot's control inputs, to atmosphere. The control task of the pilot. Flying qualities of aircraft- relation to airframe transfer function. Reversible and irreversible flight control systems. Pilot's opinion ratings. Flying quality requirements- pole-zero, frequency response and time-response specifications. Stability augmentation systems- displacement and rate feedback- determination of gains- conflict with pilot inputs- resolution- control augmentation systems. Full authority fly-by-wire control- need for automatic control.

Autopilots- purpose, functioning- inputs- hold, command, track. Displacement autopilots- pitch, yaw, bank, altitude and velocity hold- purpose, relevant

simplified aircraft transfer functions, feedback signals, control actuators-operation, analysis, performance. Manoeuvering autopilots- normal acceleration, turn rate, pitch rate commands- applications. Autopilot design by displacement and rate feedback- iterative methods, design by displacement feedback and series PID compensator - Zeigler and Nichols method. Autopilots viewed as stability augmenters. Robust control. Typical aircraft autopilots of civil and military aircraft- description of design, construction, operation, performance.

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UNIT- V

Modern Control Theory- State Space Modeling, Analysis: Limitations of classical methods of control system modeling, analysis and design, applied to complex, multiple input multiple output systems. State space modeling of dynamical systems- state variables definition- state equations. The output variable- the output equation- representation by vector matrix first order differential equations. General form, time invariant linear systems. Matrix transfer function. State transition matrix- matrix exponential- properties-numerical solution of state equations- illustrative examples. Canonical transformation of state equations- significance- eigenvalues- real distinct, repeated, complex. Controllability and observability- definition- significance. Digital control systems- overview- advantages, disadvantages.

TEXT BOOKS

1 Kuo, B.C., *Automatic Control Systems,* Prentice Hall India, 1992, ISBN 0-87692-133-0.

2 Stevens, B.L. and Lewis, F.L., Aircraft Control and Simulation, John Wiley, 1992, ISBN0-471-61397-5.

3 Nelson, R.C., *Flight Stability and Automatic Control,* second edition, Tata McGraw-Hill, 2007, ISBN: 0-07-066110-3.

4 Yechout, T.R. et al., Introduction to Aircraft Flight Mechanics, AIAA, 2003, ISBN 1-56347-577-4.

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REFERENCES

1. Mc Lean, D., *Automatic Flight Control Systems,* Prentice Hall, 1990, ISBN: 0-13-154008-0.

2. Bryson, A.E., *Control of Aircraft and Spacecraft,* Princeton University Press, 1994, ISBN: 0-691-08782-2.

3. Collinson, R.P.G., *Introduction to Avionics Systems,* second edition, Springer, 2003, ISBN: 978-81-8489-795-1.

Outcome: *The student should be able to model and estimate the performance of a specified control system including aircraft flight control systems.*

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(A72116) ADVANCED COMPUTATIONAL AERODYNAMICS

(Elective- I)

Aim: To impart knowledge and equip the students which CFD tools in subsonic, transonic super solic inviscid and viscous flows.

UNIT- I

Panel Methods: Basic formulation, boundary conditions, physical considerations, reduction of a problem to a set of linear algebraic equations, aerodynamic loads, preliminary considerations prior to establishing numerical solution, steps toward constructing a numerical solution, Solution of thin airfoil with lumped vortex filament, accounting for effects of compressibility and viscosity. Two-dimensional constant-strength singularity elements-sources, doublets and vortices, Two-dimensional constant strength singularity solutions using Neumann and Dirichlet boundary conditions-constant source, doublet and vortex methods

UNIT- II

Method of Characteristics, Boundary Conditions: Philosophy of method of characteristics, determination of characteristic lines-two-dimensional irrotational flow, determination of compatibility equations, unit processes, supersonic nozzle design by the method of characteristics-supersonic wind tunnel nozzle, minimum length nozzles, Domain of dependence and range of influence.

Concept of dummy cells, Solid wall-inviscid flow, Viscous flow, Farfield-concept of characteristic variables, modifications for lifting bodies, Inlet/output boundary, Injection boundary, symmetry plane, coordinate cut, periodic boundaries, interface between grid blocks, flow gradients at boundaries of unstructured grids

UNIT- III

Numerical Solution of Transonic Small Disturbance Equation: Physical aspects of transonic flows-critical Mach number, drag divergence Mach number, area rule, supercritical airfoils, theoretical aspects of transonic flows-transonic similarity. Derivation of Transonic Small Disturbance(TSD) equation, finite difference formulation of TSD equation, Murman- Cole switching/ upwinding in supersonic flow regions, boundary conditions, iterative solution methods for discretized TSD equation

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UNIT- IV

Numerical Solution of Euler Equations, Boundary Layer Equations: Flux

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approach- Lax-Wendroff method, Basic principles of upwind schemes, Flux-vector splitting- Steger-Warming flux vector splitting, Van Leer flux vector splitting, Upwind reconstruction- evolution- Godunov's first order upwind method, Roe's first order upwind method.

Setting up the boundary layer equations- flat plate boundary layer solution, Boundary-layer transformations- explicit and implicit discretization- solution of the implicit difference equations- integration of the continuity equation. Boundary layer edge and wall shear stress, Keller-box scheme.

UNIT- V

Time Dependent Methods: Stability of solution, explicit methods, FTFS, FTCS, FTBS, Lax method- leapfrog method, Lax method- implicit methods- Euler's FTCS, Crank-Nicolson method. Description of Lax- Wendroff scheme, McCormack two step predictor-corrector method, Description of time split methods, Approximate factorization schemes

TEXT BOOKS

1. Tannehill, John C , Anderson, Dale A, , Pletcher Richard H., *Computational Fluid Mechanics and Heat Transfer*, Second Edition, Taylor & Francis, 1997
2. Chung, T. G., *Computational Fluid Dynamics*, Second Edition, Cambridge University Press, 2010

REFERENCES

1 Katz, Joseph and Plotkin, Allen, *Low-Speed Aerodynamics,* Second Edition, Cambridge University Press, 2006.
2 Anderson, J. D., *Modern Compressible Fluid Flow,* McGraw Hill, 1982.
3 Anderson, J. D., *Fundamentals of Aerodynamics,* Fifth Edition, Tata McGraw Hill, 2010
4 Anderson, J. D., *Computational Fluid Dynamics,* McGraw Hill
5 Rathakrishnan, E., *Gasdynamics*, Prentice-Hall India, 2004
6 Laney, C. B., *Computational Gasdynamics,* Cambridge University Press, 1998
7 Schlichting, H. and Gersten, K., *Boundary-Layer Theory,* Springer, 2000
8 Blazek, J., Computational Fluid Dynamics: Principles and Applications, 2nd Edition, Elsevier, 2007

Outcome:

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The students will able to solve complex aerodynamic problems relating to aero space vehicles using CFD techniques.

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(A72121) FLIGHT SCHEDULING AND OPERATIONS

(Elective- I)

Aim: To against the students with various aspects of flight operations & scheduling.

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UNIT-I

Network Flows And Integer Programming Models : Complexity of airline planning, operations and dispatch- need for optimization- role of operations research and simulation. Networks- definitions, network flow models- shortest path problem, minimum cost flow problem, maximum flow problem, multi-commodity problem. Integer programming models- set covering/ partitioning problems, traveling salesman problem- mathematical formulation- decision variables, objective function, constraints, methods of solution. Solution by simulation.

UNIT-II

Aircraft routing & management of irregular operations: Goal of aircraft routing- maintenance requirements, other constraints. Routing cycles, route generators. Mathematical models of routing- decision variables, objective functions, alternatives, constraints- flight coverage and aircraft available. Example problems and solutions. The problem statement, the time band approximation model- formulation of the problem- the scenarios- solution.

UNIT-III

Flight Scheduling: Significance of flight scheduling. The route system of the airlines- point-to-point flights, hub and spoke flights. Schedule construction- operational feasibility, economic viability. Route development and flight scheduling process- load factor and frequency- case study.

UNIT-IV

Fleet Assignment & Crew and Manpower Scheduling : Purpose of fleet assignment. Fleet types, fleet diversity, fleet availability- performance measures, Formulation of the fleet assignment problem- decision variables, objective function, constraints, solution. Scenario analysis, fleet assignment models.

Crew scheduling process- significance. Development of crew pairing- pairing generators- mathematical formulation of crew pairing problem- methods of solution. Crew rostering- rostering practices. The crew rostering problem- formulation, solutions. Manpower scheduling- modeling, formulation of the problem, solutions.

UNIT-V

Gate Assignment and Aircraft Boarding Strategy: Gate assignment-significance- the problem- levels of handling-passenger flow, distance matrix-mathematical formulation, solution. Common strategies for aircraft boarding process, mathematical model, interferences, model description, aisle interferences.

TEXT BOOK

1 Bazargan, M.,'Airline Operations and Scheduling', 2nd edn., Ashgate Publishing Ltd, 2010.

REFERENCES

1. Belobaba, P., Odoni, A., Barnhart, C. 'The Global Airline Industry', Wiley, 2009.
2. Wu, Cheng-Lung, 'Airline Operations and Delay Management', Ashgate Publishing Ltd, 2010.
3. Wensveen, J.G., 'Air Transportation: A Management Perspective', 6th edn., Ashgate Publishing Ltd, 2007.
4. Ahuja,R. et al, 'Network Flows-Theory, Algorithms and Applications', Prentice-Hall, 1993.
5. Yu, G., "Operations Research in Airlines Industry", Academic Publishers, 1998.
6. www.airlinestechnology.net

Outcome: The student will be able to do some trouble shooting of flight scheduling & operations.

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(A72123) MECHANISMS AND MECHANICAL DESIGN

(Elective – I)

Aim: The subject gives in depth knowledge on general mechanisms and mechanical design of which aircraft systems are important component.

UNIT – I

Mechanisms: Elements of links : classification, Types of kinematic pairs: Lower and higher pairs, closed and open pairs. Constrained motion. Kinematic chain, inversions of mechanisms: inversion of quadratic cycle. Chain – single and double slider crank chains.

Exact and approximate straight line mechanisms - Peaucellier, Hart Tchebicheff, Pantograph.

Steering gear mechanisms: Condition for correct steering – Davis steering gear, Ackerman's steering gear– Hook's Joint: single and double Hooks joint , applications.

UNIT – II

Kinematic Analysis and Design of Mechanisms:

Kinematic analysis: Velocity and acceleration. Motion of link in machine – determination of velocity and acceleration diagrams –graphical method. Application of relative velocity method for four bar chain. Analysis of slider crank chain for displacement, Velocity and acceleration of sliding – Acceleration diagram for a given mechanism, Kleins construction, Coriolis acceleration, Determination of Coriolis component of acceleration.

Instantaneous centre of rotation, centroids and axodes – Relative motion between two bodies – Three centres in line theorem – Graphical determination of instantaneous centre, diagrams for simple mechanisms and determination of angular velocity of points and links.

Kinematic Design: Four bar mechanism, Freudenstein equation. Precession point synthesis, Chebyshev's method, structural error

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UNIT – III

Gyroscope – Precessional Motion: The gyroscope- free and restrained-working principle- the free gyro, rate gyro, integrating gyro as motion measuring instruments. Effect of precession on the stability of vehicles-motorbikes, automobiles, airplanes and ships. Static and dynamic forces generated due to in precession in rotating mechanisms.

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UNIT – IV

CAMS and Followers: Cams and followers- definition, uses – types– terminology. Types of follower motion- uniform velocity, simple harmonic motion and uniform acceleration. Maximum velocity and acceleration during outward and return strokes. Roller follower, circular cam with straight, concave and convex flanks.

UNIT – V

Gears and Gear Trains: Introduction to gears- types, law of gearing. Tooth profiles- specifications, classification- helical, bevel and worm gears, simple and reverted gear train, epicyclic gear trains- velocity ratio or train value.

TEXT BOOKS

1. . The Theory of machines- Thomas Beven., Third Edition – Pearson Publishers.
2. Theory of machines and Mechanisms Third Edition- John J. Uicker, Jr. Gordon R. Pennock, Joseph E. Shigley, Oxford Publisher.

REFERENCES

1. Mechanism and MachineTheory – J. S. Rao, R.V.D. Dukkipati, New Age Publishers.
2. Theory of Machines,- IIIrd Edition Sadhu Singh, Pearson Publishers.
3. Mechanism and MachineTheory – Ambekar, PHI.
4. Theory of Machines IIIrd edition S. S. Rattan, Mc. Graw - Hill.
5. A Text books of Theory of Machines by Dr. R. K. Bansal, Dr. J. S. bra r- Lakshmi Publications.

Outcome: The student shall be able to decipher basic mechanisms and mechanical design of aircraft.

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(A72125) THEORY OF ELASTICITY

(Elective – I)

Aim and Objectives: The objective of the course is to provide advance knowledge in theory of elasticity. This will help students in understanding, modeling and interpreting flight vehicle structure using finite element method.

UNIT-I

Two-Dimensional Problems- I Two dimensional problems in rectangular co-ordinates-solution by polynomials - Saint-venant's principle- determination of displacements-bending of simple beams-application of Fourier series methods for two dimensional problems - gravity loading.

UNIT-II

Two-Dimensional Problems- II Two dimensional problems in polar coordinates - stress distribution symmetrical about an axis - pure bending of curved bars - strain components in polar coordinates – displacements - displacement for symmetrical stress distribution - simple symmetric and asymmetric problems - general solution of two-dimensional problem in polar coordinates - application of general solution in polar coordinates.

UNIT-III

Three-Dimensional Problems Analysis of stress and strain in three dimensions - principal stress - stress ellipsoid - director surface - determination of principal stresses - maximum shear stresses - homogeneous deformation - principal axes of strain rotation. General theorems.

UNIT-IV

Torsion Torsion of prismatic bars - torsion of prismatic bars - bars with elliptical cross sections - other elementary solution - membrane analogy - torsion of rectangular bars-solution of torsional problems by energy method - use of soap films in solving torsion problem - hydro dynamical analogies - torsion of shafts, tubes, bars etc.

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UNIT-V

Bending Bending of prismatic Bars: Stress function - bending of cantilever - circular cross section – elliptical cross section – rectangular cross section - bending problems by soap film method - displacements

TEXT BOOK

1. Timoshenko, S.P. and Goodier, J.N., *Theory of Elasticity*, Tata McGraw Hill.

2. Sadd, M.H., Elasticity: Theory, Applications, and Numerics, Elsevier Pub, 2009.

REFERENCES

1. Chakrabarty, *Theory of Plasticity,* McGraw-Hill Publications.
2. *Fung, Y.C., An Introduction to the* Theory of Aeroelasticity, Dover Publications.
3. Gurucharan Singh, *Theory of Elasticity.* 4 Sadhu Singh, *Theory of Elasticity*, Khanna Publications.

Outcome: At the end of this course, students will be in a position to handle complex problems for flight structural analysis.

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(A70008) PROBABILITY AND STATISTICS

(Elective – I)

Objectives: To learn

- Understand a random variable that describes randomness or an uncertainty in certain realistic situation. It can be of either discrete or continuous type.
- In the discrete case, study of the binomial and the Poisson random variables and the Normal random variable for the continuous case predominantly describe important probability distributions. Important statistical properties for these random variables provide very good insight and are essential for industrial applications.
- Most of the random situations are described as functions of many single random variables. In this unit, the objective is to learn functions of many random variables through joint distributions.
- The types of sampling, Sampling distribution of means ,Sampling distribution of variance,Estimations of statistical parameters, Testing of hypothesis of few unknown statistical parameters.
- The mechanism of queuing system ,The characteristics of queue,The mean arrival and service rates
- The expected queue length, The waiting line
- The random processes, The classification of random processes, Markov chain, Classification of states
- Stochastic matrix (transition probability matrix), Limiting probabilities, Applications of Markov chains

UNIT-I

Single Random variables and probability distributions: Random variables – Discrete and continuous. Probability distributions, mass function/ density function of a probability distribution . Mathematical Expectation, Moment about origin, Central moments Moment generating function of probability distribution.

Binomial, Poisson & normal distributions and their properties. Moment generating functions of the above three distributions, and hence finding the mean and variance.

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UNIT-II

Multiple Random variables, Correlation & Regression: Joint probability distributions- Joint probability mass / density function, Marginal probability

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mass / density functions, Covariance of two random variables, Correlation - Coefficient of correlation, The rank correlation.

Regression- Regression Coefficient, The lines of regression and multiple correlation & regression.

UNIT-III

Sampling Distributions and Testing of Hypothesis

Sampling: Definitions of population, sampling, statistic, parameter. Types of sampling, Expected values of Sample mean and varience, sampling distribution, Standard error, Sampling distribution of means and sampling distribution of varience.

Parameter estimations – likelihood estimate, interval estimations.

Testing of hypothesis: Null hypothesis, Alternate hypothesis, type I, & type II errors – critical region, confidence interval, Level of significance. One sided test, two sided test,

Large sample tests:

(i) Test of Equality of means of two samples equality of sample mean and population mean (cases of known varience & unknown varience, equal and unequal variances)

(ii) Tests of significance of difference between sample S.D and population S.D.

(iii) Tests of significance difference between sample proportion and population proportion&difference between two sample proportions.

Small sample tests:

Student t-distribution,its properties; Test of significance difference between sample mean and population mean; difference between means of two small samples Snedecor's F- distribution and it's properties. Test of equality of two population variences Chi-square distribution , it's properties, Chi-square test of goodness of fit

UNIT-IV

Queuing Theory: Structure of a queuing system, Operating Characteristics of queuing system, Transient and steady states, Terminology of Queuing systems, Arrival and service processes- Pure Birth-Death process Deterministic queuing models- M/M/1 Model of infinite queue, M/M/1 model of finite queue .

UNIT-V

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Stochastic processes: Introduction to Stochastic Processes –Classification of Random processes, Methods of description of random processes, Stationary and non-stationary random process, Average values of single random process and two or more random processes. Markov process,

Markov chain, classification of states – Examples of Markov Chains, Stochastic Matrix.

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TEXT BOOKS:

1) Higher Engineering Mathematics by Dr. B.S. Grewal, Khanna Publishers

2) Probability and Statistics for Engineers and Scientists by Sheldon M.Ross, Academic Press

3) Operations Research by S.D. Sarma,

REFERENCE BOOKS:

1. Mathematics for Engineers by K.B.Datta and M.A S.Srinivas,Cengage Publications

2. Probability and Statistics by T.K.V.Iyengar & B.Krishna Gandhi Et

3. Fundamentals of Mathematical Statistics by S C Gupta and V.K.Kapoor

4. Probability and Statistics for Engineers and Scientists by Jay I.Devore.

Outcomes:

- Students would be able to identify distribution in certain realistic situation. It is mainly useful for circuit as well as non-circuit branches of engineering. Also able to differentiate among many random variable involved in the probability models. It is quite useful for all branches of engineering.
- The student would be able to calculate mean and proportions (small and large sample) and to make important decisions from few samples which are taken out of unmanageably huge populations .It is Mainly useful for non-circuit branches of engineering.
- The students would be able to find the expected queue length, the ideal time, the traffic intensity and the waiting time. These are very useful tools in many engineering and data management problems in the industry. It is useful for all branches of engineering.
- The student would able to understand about the random process, Markov process and Markov chains which are essentially models of many time dependent processes such as signals in communications, time series analysis, queuing systems. The student would be able to find the limiting probabilities and the probabilities in n^{th} state. It is quite useful for all branches of engineering

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(A72124) SPACE MECHANICS

(Elective- II)

Aim: The Concepts of space mechanics are taught to familiarize the student with satellite and missile launch vehicle dynamics.

UNIT- I

Basic Concepts: The solar system, comets and meteors, Kepler's laws and Newton's law of gravitation, concept of celestial sphere, vernal equinox, ecliptic. Coordinate systems- ECI system, geographic coordinate system, azimuth-elevation coordinate system, ecliptic system, Time systems- sidereal time, mean solar time, Julian date, universal time, ephemeris time.

UNIT- II

Two-Body and Restricted Three Body Problems : N-body problem, two-body problem- simplifying assumptions. Equations of relative motion. Constants of the motion- conservation of angular momentum, Trajectory equation, elliptical orbit- geometry of the ellipse, period of an elliptical orbit, circular orbit, parabolic orbit, hyperbolic orbit. Geometry of the hyperbola, hyperbolic excess speed. Orbital elements.

Introduction, equations of motion, Lagrangian points, stability of the Lagrangian points, Jacobi's integral, accessible regions.

UNIT- III

Basic Orbital Maneuvres and Orbit Perturbations : Low altitude earth orbits- effect of orbital altitude on satellite life times, direct ascent to orbit, perturbations of low earth orbits due to the oblate shape of the Earth. High altitude earth orbits- the synchronous satellite, launching a high altitude satellite. In-plane orbit changes- adjustment of perigee and apogee height, Hohmann transfer, general coplanar transfer between circular orbits, Out-of plane orbit changes-simple plane change.

General overview of orbit perturbations, Earth gravity harmonics, lunisolar gravitational attractions, solar radiation pressure effects, atmospheric drag effects, tidal friction effects and mutual gravitational attraction. earth's oblateness (J_2) effects, critical inclination. Sun-synchronous orbits, J_3 effects and frozen orbits, Earth's triaxiality effects and east-west station keeping.

UNIT- IV

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Ballistic Missile Trajectories: The general ballistic missile problem-geometry of the trajectory, free flight range equations, flight path angle equation, maximum range trajectory, time of free flight. Effect of launching

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errors on range- effect of lateral displacement of the burnout point, cross range error due to incorrect launch azimuth, effect of down range displacement of the burnout point, errors in burn-out flight-path angle, down range errors caused by incorrect burnout height and in correct speed at burnout. The effect of earth rotation- compensating for the initial velocity of missile due to earth rotation, compensating for movement of the target due to earth rotation.

UNIT- V

Interplanetary Trajectories: Patched-conic approximation-heliocentric transfer orbit, phase angle at departure, escape from the earth's sphere of influence, arrival at the target planet, effective collision cross-section. Locating the planets- launch opportunity, synodic period, trajectory type and class, ephemeris calculations, Non-coplanar interplanetary trajectories, Gravity-assist manoeuvre. Fast interplanetary trajectories.

TEXT BOOKS

1 Bate, R.R., Mueller, D.D. and White, J.E., *Fundamentals of Astrodynamics*, Dover Publications Inc., New York, 1971.

REFERENCES

1. Wiesel, W.E., *Space?ight Dynamics,* 2nd edn., McGraw-Hill, New York, 1995.
2. Hale, F.J., *Introduction to Space Flight,* Prentice Hall, 1994.
3. Sellers, J.J., *Understanding Space: An Introduction to Astronautics*, 2nd edn., McGraw-Hill, 2004
4. Chobotov, V.A., ed, *Orbital Mechanics* 3rd edn., AIAA Education Series, 2002.

Outcome: The student will be able to estimate space mechanics associated space vehicles.

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(A72120) EXPERIMENTAL AERODYNAMICS

(Elective- II)

Aim: The student will learn fundamental underlying theory of all experiments and in particular about different aerodynamic measurement techniques in a wind tunnel. He/she will acquire skills to design wind tunnels and to use various instruments and sensors used in a wind tunnel. He will appreciate how essential it is to perform experiments for the advancement of theory.

UNIT- I

Aerodynamic Experiments- History, Model Testng, Types Of Wind Tunnels: Forms of aerodynamic experiments- observation, measurement- objectives. History – Wright brothers' wind tunnel,, Model testing- wind tunnel- principles- scaling laws, scale parameters, similarity- geometric,, kinematic & dynamic.

Wind tunnels- low speed- types, description. High speed tunnels- transonic, supersonic, hypersonic, shock tubes, special tunnels- low turbulence, high Re, environmental, automobile- function, distinctive features, application.

UNIT- II

Low Speed Wind Tunnels- Detailed Design Features & Corrections: Low speed wind tunnel- principal components- working section, diffuser, corners, turning vanes, fan, straighteners, honeycombs, screens, contraction cone, fan, motor- function, description, design requirements, constraints, construction, performance- loss coefficients. Wind tunnel performance- flow quality, power losses.

Wind tunnel corrections. Sources of inaccuracies- bouyancy, solid blockage, wake blockage, streamline curvature- causes, estimation and correction..

UNIT- III

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Low Speed Balances & High Speed Tunnels : Load measurements- Low speed wind tunnel balances – MECHANICAL & strain gage types, Null displacement method & Strain method, sensitivity, Weighbeams – Steelyard type and Current-balance type, Balance Linkages - Levers & Pivots, Model support – three point wire support, three-point strut support,. Mechanical balance – Platform balance , Yoke balance; What is a strain gage, 3-component straingage balance. description, application.

Basic features of Transonic wind tunnels, Supersonic wind tunnels— Blow Down and Suction – basic features, Shock tubes & hypersonic gun tunnel.

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UNIT- IV

Pressure Velocity Temperature Measurements & Flow Visualisation Techniques -1: LOW SPEED MEASUREMENTS: Streamlines, Streak lines, Path lines, Time lines.

measurement of airspeed, flow direction, boundary layer profile using Pitot-static tubes, 5 hole probe yaw meter,, total head rake- function, working principle,

Flow visualisation- need,, types- tufts, china clay, oil film, smoke, hydrogen bubble - working principle, description, setting up, operation, observation, recording, interpretation of imagery, relative merits, applications.

HIGH SPEED MEASUREMENTS: Static pressure — surface pressure orifice, static probes, Pitot probe for total pressure, Mach number from pressure measurements, Wedge & Cone measurements — static pressure & flow angularity, Temperature & heat transfer measurements.

Flow Visualization in High speed flows- optical methods- Density & refractive index, Schlieren system — convex lenses, knife edge, concave mirrors as replacement for lenses; Shadowgraph ;, interferometer.

UNIT-V

Pressure Velocity Temperature Measurements & Flow Visualisation Techniques – 2: Steady and unsteady pressure measurements and various types of pressure probes and transducers, errors in pressure measurements; measurement of temperature using thermocouples, resistance thermometers, temperature sensitive paints and liquid crystals

Hot Wire Anemometry, Laser Doppler Anemometry, Partcle Image Velocimetry- working principles, description of equipment, experimental setup, settings, calibration, measurement, data processing, applications.

TEXT BOOKS

1. Low Speed Wind Tunnel Testing, Barlow, J.B., Rae, W.H., Pope, A., Wiley 1999.
2. High Speed Wind Tunnel Testing, Pope, A. and Goin, K.L., Wiley, 1965.
3. Bradshaw, P., *Experimental Fluid Mechanics,* Pergamon Press, 1970.
4. Liepmann, H.W., and Roshko, A., *Elements of Gas Dynamics*, John Wiley, 1957 (Chapter 6: Methods of Mesurement).

REFERENCES

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1. Yang, W.J., *Handbook of Flow Visualization,* 2nd edition, Taylor and Francis, 2001.

2. Goldstein, R.J., (Ed.) *Fluid Mechanics Measurements*, Taylor Francis, Washington 1996. 84.

3. Tropea, C., Yarin, A. L., Foss, J. F., *Handbook of Experimental Fluid Mechanics*, Springer, 2007.

Outcome: Students will be able to know how to use instruments and sensors used in wind tunnels.

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(A70352) OPERATIONS RESEARCH

(Elective-II)

UNIT – I

Development – Definition– Characteristics and Phases – Types of models – Operations Research models – applications.

Allocation: Linear Programming Problem Formulation – Graphical solution – Simplex method – Artificial variables techniques: Two-phase method, Big-M method.

UNIT – II

Transportation Problem – Formulation – Optimal solution, unbalanced transportation problem – Degeneracy.

Assignment problem – Formulation – Optimal solution - Variants of Assignment Problem- Traveling Salesman problem.

UNIT – III

Sequencing – Introduction – Flow –Shop sequencing – n jobs through two machines – n jobs through three machines – Job shop sequencing – two jobs through 'm' machines

Replacement: Introduction – Replacement of items that deteriorate with time – when money value is not counted and counted – Replacement of items that fail completely- Group Replacement.

UNIT – IV

Theory of Games: Introduction –Terminology– Solution of games with saddle points and without saddle points- 2 x 2 games – dominance principle – m x 2 & 2 x n games -graphical method.

Inventory: Introduction – Single item, Deterministic models – Purchase inventory models with one price break and multiple price breaks –Stochastic models – demand may be discrete variable or continuous variable – Single Period model and no setup cost.

UNIT – V

Waiting Lines: Introduction – Terminology-Single Channel – Poisson arrivals and Exponential Service times – with infinite population and finite population models– Multichannel – Poisson arrivals and exponential service times with infinite population.

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Dynamic Programming:

Introduction – Terminology- Bellman's Principle of Optimality – Applications

of dynamic programming- shortest path problem – linear programming problem.

Simulation: Introduction, Definition, types of simulation models, Steps involved in the simulation process- Advantages and disadvantages- applications of simulation to queuing and inventory.

TEXT BOOK :

1. Operations Research /J.K.Sharma 4e. /MacMilan
2. Introduction to O.R/Hillier & Libermann/TMH

REFERENCE BOOKS :

1. Introduction to O.R /Taha/PHI
2. Operations Research/ NVS Raju/ SMS Education/3rd Revised Edition
3. Operations Research /A.M.Natarajan, P.Balasubramanian, A. Tamilarasi/Pearson Education.
4. Operations Research / Wagner/ PHI Publications.
5. Operations Research/M.V. Durga Prasad, K. Vijaya Kumar Reddy, J. Suresh Kumar/ Cengage Learning.

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(A72117) AIRCRAFT MAINTENANCE ENGINEERING

(Elective- II)

Aim: To familiarize the students with various aspects of aviation maintenance.

UNIT- I

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Philosophy of Aircraft Maintenance: Definition of maintenance, Objectives of a maintenance program, Outline of aviation maintenance program, summary of FAA requirements, additional maintenance program requirements; Organization of maintenance and engineering, organization structure, M&E organization chart, general groupings, Managerial Level Functions-technical services, aircraft maintenance, overhaul shops, material, maintenance program evaluation directorates, summary of management levels, organization structure and TPPM, variations from the typical organization role of the engineer, role of the mechanic, two types of maintenance, reliability, redesign, failure rate patterns, other maintenance considerations, establishing a maintenance program. Goals and objectives of maintenance, Discussion of the five objectives

UNIT- II

Development of Maintenance Programs: Maintenance Steering Group(MSG) Approach, Process-Oriented maintenance, Task-oriented maintenance, Current MSG process-MSG-3, Maintenance program documents, maintenance intervals defined, changing basic maintenance intervals, maintenance program content

UNIT- III

Technical Services: Engineering: makeup of engineering, mechanics and engineers, engineering department functions, engineering order preparation; Production Planning & Control-forecasting, production planning, production control, feedback for planning, organization of PP&C; Technical Publications-functions of technical publications, airline libraries, control of publications, document distribution; Technical Training-organization, training for aviation maintenance, airframe manufacturer's training courses, other airline training courses; Computer support-airlines uses of computers

UNIT- IV

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Maintenance and Material Support: Line Maintenance(on-aircraft)-makeup of line maintenance, functions that control maintenance, maintenance control centre responsibilities, general line maintenance operations, aircraft logbook, ramp and terminal operations, other line maintenance activities, line station activities, maintenance crew requirements, morning meeting; Hangar

Maintenance(on-aircraft)-organization of hangar maintenance, problem areas in hangar maintenance, maintenance support shops, ground support equipment, typical C-check; Maintenance overhaul shops(off-aircraft)-organization, types and operation of overhaul shops, Shop data collection; Material support-organization and function of material, material directorate, M&E support functions

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UNIT- V

Maintenance Documentation and Quality Assurance : Aircraft certification, delivery inspection, operator certification, certification of personnel, aviation industry interaction; Types of documentation, manufacturer's documentation, regulatory documentation, airline generated documentation, ATA document standards, closer look of TPPM, Quality Assurance-requirements for QA, quality audits, ISO 9000 quality standard, technical records, other functions of QA; Quality Control-quality control organization, FAA and JAA differences, QC inspector qualifications, basic inspection policies, other QC activities; Reliability-definition and types of reliability, elements of a reliability program,

TEXT BOOKS

1. Kinnison, H.A., *Aviation Maintenance Management*, McGraw-Hill, 2004.
2. McKinley, J. L., Bent, R.D., *Maintenance and Repair of Aerospace Vehicles*, Northrop Institute of Technology, McGraw Hill, 1967.

REFERENCES

1. Friend, C.H., *Aircraft Maintenance Management*, Longman, 1992.
2. Kroes, M., Watkins, W., and Delp, F. *Aircraft Maintenance and Repair*, Tata McGraw-Hill, 2010.
3. Patankar, M.S. And Taylor, J.C., Risk Management and Error Reduction in Aviation Maintenance, Ashgate, 2004, ISBN 0-7546-1941-9.
4. *Aircraft Communication & Navigation System- Principles, maintenance & Operation*, Mike Tooley & David Wyatt, Rootledge, 2013
5. *Engineering Maintenance- A Modern Approach, B.S. Dhillon, CRC Press, 2013.*

Outcome: The Students will be able to trouble shoot problems in aircraft maintenance.

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(A72187) COMPUTATIONAL STRUCTURES LAB

1, 2. Introduction to the features and application of any one of the professional software employed in modelling and analysis of aircraft structures.

MODELING, ANALYSIS (MAXIMUM STRESSES, DEFLECTIONS) AND CODE DEVELOPMENT, OF STRUCTURAL ELEMENTS UNDER ARBITRARY STATIC LOADING- VALIDATION OF SOLUTIONS WITH PROFESSIONAL SOFTWARE

3. Bending of uniform cantilever beams.
4. Compressive strength of rectangular stiffened plane panels of uniform cross-section.
5. Shear and torsion of stiffened thin walled open and closed sections.
6. Statically indeterminate trusses.
7. Free vibrations of uniform cantilever beams- determination of natural frequencies and mode shapes.

MODELING AND ANALYSIS OF SIMPLE AIRCRAFT COMPONENTS USING PROFESSIONAL SOFTWARE

8. 3 dimensional landing gear trusses.
9. Tapered wing box beams.
10. Fuselage bulkheads.

Suggested soft wares

ANSYS
NASTRAN
PATRAN

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(A72186) COMPUTATIONAL AERODYNAMICS LAB

1. Introduction to any one of the suitable software employed in modelling and simulation of aerodynamics problems.

2, 3. Solution for the following equations using finite difference method (Code development):

   i) One-dimensional wave equation using explicit method of Lax

   ii) One-dimensional heat conduction equation using explicit method

4, 5. Generation of the following grids (Code development):

   i) Algebraic grids

   ii) Elliptic grids

6,7,8,9,10. Numerical Simulation of the following flow problems using commercial software packages:

   i) Flow over an airfoil

   ii) Supersonic flow over a wedge

   iii) Flat plate boundary layer

   iv) Laminar pipe flow

   v) Flow past a cylinder

Suggested Software:

FLUENT

CFX

MATLAB

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