B. Tech. in AERONAUTICAL ENGINEERING

Syllabus of Paper – 1

ELEMENTS OF AERONAUTICS

History of Flight: Balloon flight – ornithopters - early airplanes by wright brothers, biplanes and monoplanes, developments in aerodynamics, materials, structures and propulsion over the years. Basics of Flight Mechanics: Physical properties and structure of the atmosphere, temperature, pressure and altitude relationships, newton's law of motions applied to aeronautics - evolution of lift, drag and moment. aerofoils, mach number, maneuvers. Aircraft Configurations: Different types of flight vehicles, classifications. components of an airplane and their functions. conventional control, powered control, basic instruments for flying - typical systems for control actuation. Airplane Structures and Materials: General types of construction, monocoque, semi-monocoque and geodesic constructions, typical wing and fuselage structure. metallic and non-metallic materials, use of aluminium alloy, titanium, stainless steel and composite materials. stresses and strains – hooke's law – stress - strain diagrams - elastic constants. Power Plants: Basic ideas about piston, turboprop and jet engines - use of propeller and jets for thrust production - comparative merits, principles of operation of rocket, types of rockets and typical applications, exploration into space.

AERODYNAMICS - I

Introduction to Low Speed Flow: Euler equation, incompressible Bernoulli's equation. circulation and vorticity, green's lemma and stoke's theorem, barotropic flow, kelvin's theorem, streamline, stream function, irrotational flow, potential function, equipontential lines, elementary flows and their combinations. Two Dimensional Inviscid Incompressible Flow: Ideal Flow over a circular cylinder, D'Alembert's paradox, magnus effect, Kutta joukowski's theorem, starting vortex, kutta condition, real flow over smooth and rough cylinder. Airfoil Theory: Cauchy-Riemann relations, complex potential, methodology of conformal transformation, kutta-joukowski transformation and its applications, thin airfoil theory and its applications. Subsonic Wing Theory: Vortex filament, Biot and Savart law, bound vortex and trailing vortex, horse shoe vortex, lifting line theory and its limitations. Introduction to Boundary Layer Theory: Boundary layer and boundary layer thickness, displacement thickness, momentum thickness, energy thickness, shape parameter, boundary layer equations for a steady, two dimensional incompressible flow, boundary layer growth over a flat plate, critical reynolds number, blasius solution, basics of turbulent flow.

AERODYNAMICS – II

Fundamental Aspects of Compressible Flow: Compressibility, continuity, momentum and energy equations for steady one dimensional flow, compressible Bernoulli's equation, area – mach number – velocity relation, mach cone, mach angle, one dimensional isentropic flow through variable area duct, critical conditions, characteristic mach number, area-mach number relation, maximum discharge velocity – operating characteristics of nozzles- introduction to hypersonic flows. Shock and Expansion Waves: Normal shock relations, Prandtl's relation, Hugoniot equation, Rayleigh Supersonic Pitot tube equation, Moving normal shock waves, Oblique shocks, M relation, Shock Polar, Reflection of oblique shocks, left running and right running waves, Interaction of oblique shock waves, slip line, shock-boundary layer interaction – transonic lambda shock – compression corner effect – incident shock interaction - Rayleigh flow, Fanno flow, Expansion waves, Prandtl-Meyer expansion, Maximum turning angle, Simple and non-

simple regions. Two Dimensional Compressible Flow: Potential equation for 2-dimensional compressible flow, Linearisation of potential equation, perturbation potential, Linearised Pressure Coefficient, Linearised subsonic flow, Prandtl-Glauert rule, Linearised supersonic flow, Method of characteristics. High Speed Flow Over Airfoils, Wings and Airplane Configuration: Critical Mach number, Drag divergence Mach number, Shock Stall, Supercritical Airfoil Sections, Transonic area rule, Swept wing, Airfoils for supersonic flows, Lift, drag, Pitching moment and Centre of pressure for supersonic profiles, Shock-expansion theory, wave drag, supersonic wings, Design considerations for supersonic aircraft- aerodynamic heating. Experimental Techniques for High Speed Flows: Wind tunnels for transonic, Supersonic and hypersonic flows, shock tube, Gun tunnels-peculiar problems in the operation of hypersonic tunnels - Supersonic flow visualization methods.

AIRCRAFT PERFORMANCE

The Standard Atmosphere and Airflow: Standard atmosphere, Relation between geo-potential and geometric altitudes, Pressure, temperature and density altitudes. Relations for isothermal and gradient atmospheric regions, Stability of atmosphere, Measurement of air-speed: Indicated airspeed, Calibrated airspeed, Equivalent airspeed and True airspeed, Airspeed indicator. Aerodynamic Drag: Drag, Causes of drag, Types of drag, Factors affecting drag. Drag polar, Compressibility drag, Design for minimum drag, Estimation of drag of complete airplane for subsonic and supersonic cases, Terminal velocity. Aerodynamic characteristics: Force and Moment coefficients from dimensional analysis and their variation with angle of attack, Lift, Drag and moment coefficients, Relations between lift and drag, Aerodynamic center, Center of pressure, Pressure distribution over 2-D airfoil, Estimation of aerodynamic characteristics from measured pressure distribution, Variation of aerodynamic coefficients with Reynold's Number and Mach number, Effect of span, aspect ratio, plan form, sweep, taper and twist on aerodynamic characteristics of a lifting surface, Delta wing aerodynamics. High Lift Devices: Maximum lift coefficient of airfoils, Leading and trailing edge devices, The deep stall, Propulsive lift, V/STOL configurations. Aircraft Performance in Steady Flight: Straight and Level flight, Variation of drag with flight speed, Minimum drag conditions, Variation of power with flight speed, Minimum power conditions, Gliding flight, Shallow and steep angles of glide, Sinking speed, Minimum sinking speed, Time of descent, Climbing flight at shallow angles, Correction for steep angles, Time to flight, Maximum rate of climb. Aircraft Performance in Accelerated Flight: Take-off and landing, Calculation of take-off ground run and take off distances, Minimum ground run, Assisted take-off, Calculation of landing ground run and landing distances, Range and endurance, Numerical problems. Maneuvers & Energy Methods: Maneuvering performance, Introductory comments on spins and stalls, Analysis of Spin, Various types of stalling behaviour of wings, Turning flight, Maneuvers in 3-D space, Karman’s method of JATO, Energy method of performance calculations.

FLIGHT DYNAMICS

Cruising Flight Performance: Forces and moments acting on a flight vehicle - Equation of motion of a rigid flight vehicle - Different types of drag –estimation of parasite drag co-efficient by proper area method- Drag polar of vehicles from low speed to high speeds - Variation of thrust, power with velocity and altitudes for air breathing engines . Performance of airplane in level flight - Power available and power required curves. Maximum speed in level flight - Conditions for minimum drag and power required. Manoeuvering Flight Performance: Range and endurance - Climbing and gliding flight (Maximum rate of climb and steepest angle of climb, minimum rate of sink and shallowest angle of glide) -Turning performance (Turning rate turn

radius). Bank angle and load factor – limitations on turn - V-n diagram and load factor. Static Longitudinal Stability: Degree of freedom of rigid bodies in space - Static and dynamic stability - Purpose of controls in airplanes -Inherently stable and marginal stable airplanes – Static, Longitudinal stability - Stick fixed stability - Basic equilibrium equation - Stability criterion - Effects of fuselage and nacelle - Influence of CG location - Power effects - Stick fixed neutral point - Stick free stability-Hinge moment coefficient - Stick free neutral points-Symmetric maneuvers - Stick force gradients - Stick - force per 'g' - Aerodynamic balancing. Lateral And Directional Stability: Dihedral effect - Lateral control - Coupling between rolling and yawing moments - Adverse yaw effects Aileron reversal - Static directional stability - Weather cocking effect - Rudder requirements - One engine inoperative condition - Rudder lock. Dynamic Stability: Introduction to dynamic longitudinal stability: - Modes of stability, effect of freeing the stick - Brief description of lateral and directional. dynamic stability - Spiral, divergence, Dutch roll, auto rotation and spin.

AIRCRAFT MATERIALS AND PROCESSES

Elements of Aerospace Materials: Structure of solid materials – Atomic structure of materials – crystal structure – miller indices – density – packing factor – space lattices – x-ray diffraction – imperfection in crystals – physical metallurgy - general requirements of materials for aerospace applications. Mechanical Behaviour of Materials: Linear and non linear elastic properties – Yielding, strain hardening, fracture, Bauchinger's effect – Notch effect testing and flaw detection of materials and components – creep and fatigue - comparative study of metals, ceramics plastics and composites. Corrosion & Heat Treatment of Metals and Alloys: Types of corrosion – effect of corrosion on mechanical properties – stress corrosion cracking – corrosion resistance materials used for space vehicles heat treatment of carbon steels – aluminium alloys, magnesium alloys and titanium alloys – effect of alloying treatment, heat resistance alloys – tool and die steels, magnetic alloys. Ceramics and Composites: Introduction – powder metallurgy - modern ceramic materials – cermets - cutting tools – glass ceramic –production of semi fabricated forms - plastics and rubber – carbon/carbon composites, fabrication processes involved in metal matrix composites - shape memory alloys – applications in aerospace vehicle design, open and close mould processes. High Temperature Materials Characterization: Classification, production and characteristics – methods and testing – determination of mechanical and thermal properties of materials at elevated temperatures – application of these materials in thermal protection systems of aerospace vehicles – super alloys – high temperature material characterization.

Syllabus of Paper - 2

AIRCRAFT STRUCTURES – I

Statically Determinate & Indeterminate Structures: Plane truss analysis – method of joints – method of sections – method of shear – 3- D trusses – principle of super position, clapeyron's 3 moment equation and moment distribution method for indeterminate beams. Energy Methods: Strain Energy in axial, bending, torsion and shear loadings. Castigliano's theorems and their applications. Energy theorems – dummy load & unit load methods – energy methods applied to statically determinate and indeterminate beams, frames, rings & trusses. Columns: Euler's column curve – inelastic buckling – effect of initial curvature – the Southwell plot – columns with eccentricity – use of energy methods – theory of beam columns – beam columns with different end conditions – stresses in beam columns. Failure Theories: Ductile and brittle materials – maximum principal stress theory - maximum principal strain theory - maximum shear stress theory - distortion energy theory – octahedral shear stress theory. Induced Stresses: Thermal stresses – impact loading – Fatigue – Creep - Stress Relaxation.

AIRCRAFT STRUCTURES - II

Unsymmetrical Bending: Bending of symmetric beams subject to skew loads - bending stresses in beams of unsymmetrical sections – generalized 'k' method, neutral axis method, principal axis method. Shear Flow in Open Sections: Thin walled beams – concept of shear flow – the shear centre and its determination – shear flow distribution in symmetrical and unsymmetrical thin-walled sections – structural idealization – shear flow variation in idealized sections. Shear Flow in Closed Sections: Bredt - Batho theory – single-cell and multi-cell tubes subject to torsion – shear flow distribution in thin-walled single & multi-cell structures subject to combined bending torsion – with walls effective and ineffective in bending – shear centre of closed sections. Buckling of Plates: Bending of thin plates – rectangular sheets under compression - local buckling stress of thin walled sections – crippling strength estimation – thin-walled column strength – load carrying capacity of sheet stiffener panels – effective width. Stress Analysis of Wing And Fuselage: Loads on an aircraft – the V-N diagram – shear force and bending moment distribution over the aircraft wing and fuselage – shear flow in thin-webbed beams with parallel and non-parallel flanges – complete tension field beams – semi-tension field beam theory.

PROPULSION - I

Fundamentals of Air Breathing Engines: Operating principles of piston engines – thermal efficiency calculations – classification of piston engines - illustration of working of gas turbine engine – 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. Inlets, Nozzles and Combustion Chambers for Jet Engines: Internal flow and Stall in subsonic inlets – relation between minimum area ratio and eternal deceleration ratio – diffuser performance – supersonic inlets – starting problem on supersonic inlets – shock swallowing by area variation – . real flow in nozzles and nozzle efficiency – losses in nozzles – equilibrium flow and frozen flow in nozzles- two phase flow in nozzles – ejector and variable area nozzles - interaction of nozzle flow with adjacent surfaces – thrust reversal- classification of combustion chambers – combustion chamber performance – effect of operating variables on performance – flame stabilization. Compressors For Jet Engines: Principle of operation of centrifugal compressor and axial flow compressor– Work done and pressure rise – velocity diagrams – degree of reaction – free vortex and constant reaction designs of axial

flow compressor – performance characteristics of centrifugal and axial flow compressors– stage efficiency calculations – cascade testing. Turbines For Jet Engines: Principle of operation of axial flow turbines– limitations of radial flow turbines- Work done and pressure rise – Velocity diagrams – degree of reaction – free vortex and constant nozzle angle designs – performance characteristics of axial flow turbine– turbine blade cooling methods – stage efficiency calculations – basic blade profile design considerations – matching of compressor and turbine. Ramjet Propulsion: Operating principle of ramjet engine – various components of ramjet engines and their efficiencies – Combustion in ramjet engine – critical, subcritical and supercritical modes of operation -ramjet engine and its performance characteristics – sample ramjet design calculations – flame stability problems in ramjet combustors –integral ram rockets.

PROPULSION II

Hypersonic Air breathing Propulsion: Introduction to hypersonic air breathing propulsion, hypersonic vehicles and supersonic combustion-need for supersonic combustion for hypersonic propulsion – salient features of scramjet engine and its applications for hypersonic vehicles – problems associated with supersonic combustion – engine/airframe integration aspects of hypersonic vehicles – various types scramjet combustors – fuel injection schemes in scramjet combustors – one dimensional models for supersonic combustion using method of influence coefficients. Fundamentals of Chemical Rocket Propulsion: Operating principle – specific impulse of a rocket – internal ballistics – performance considerations of rockets – types of igniters- preliminary concepts in nozzle-less propulsion – air augmented rockets – pulse rocket motors – static testing of rockets & instrumentation –safety considerations. Solid Rocket Propulsion: Salient features of solid propellant rockets – selection criteria of solid propellants – estimation of solid propellant adiabatic flame temperature - propellant grain design considerations – erosive burning in solid propellant rockets – combustion instability – strand burner and T-burner – applications and advantages of solid propellant rockets. Liquid and Hybrid Rocket Propulsion : Salient features of liquid propellant rockets – selection of liquid propellants – various feed systems and injectors for liquid propellant rockets -thrust control and cooling in liquid propellant rockets and the associated heat transfer problems – combustion instability in liquid propellant rockets – peculiar problems associated with operation of cryogenic engines - Introduction to hybrid rocket propulsion – standard and reverse hybrid systems- combustion mechanism in hybrid propellant rockets – applications and limitations. Advanced Propulsion Techniques: Electric rocket propulsion– types of electric propulsion techniques - Ion propulsion – Nuclear rocket – comparison of performance of these propulsion systems with chemical rocket propulsion systems – future applications of electric propulsion systems - Solar sail.

VIBRATIONS AND ELEMENTS OF AEROELASTICITY

Single Degree of Freedom Systems: Introduction to simple harmonic motion, D'Alembert's principle, free vibrations – damped vibrations – forced vibrations, with and without damping – support excitation – transmissibility - vibration measuring instruments. Multi Degrees of Freedom Systems: Two degrees of freedom systems - static and dynamic couplings - vibration absorber- principal co-ordinates - principal modes and orthogonal conditions - Eigen value problems - Hamilton's principle - Lagrangean equations and application. Continuous Systems: Vibration of elastic bodies - vibration of strings – longitudinal, lateral and torsional vibrations. Continuous Systems: Vibration of elastic bodies - vibration of strings – longitudinal, lateral and torsional vibrations. Approximate Methods: Approximate methods - Rayleigh's method - Dunkerlay's method – Rayleigh-Ritz method, matrix iteration method. Elements of Aero elasticity: Vibration

due to coupling of bending and torsion - aeroelastic problems - collars triangle - wing divergence - aileron control reversal – flutter – buffeting – elements of servo elasticity.

AIRCRAFT SYSTEMS AND INSTRUMENTS

Aircraft Systems: Hydraulic systems – Study of typical workable systems – components – hydraulic systems controllers– modes of operation – pneumatic systems – working principles – typical pneumatic power system – brake system – components, landing gear systems – classification – shock absorbers – retractive mechanism. Airplane Control Systems: Conventional Systems – power assisted and fully powered flight controls – power actuated systems – engine control systems – push pull rod system – operating principles – modern control systems – digital fly by wire systems – auto pilot system, active control technology. Engine Systems: Fuel systems – piston and jet engines – components - multi-engine fuel systems, lubricating systems - piston and jet engines – starting and ignition systems – piston and jet engines. Air conditioning and Pressurizing System: Basic air cycle systems – vapour cycle systems, boot-strap air cycle system – evaporative vapour cycle systems – evaporation air cycle systems – oxygen systems – fire protection systems, deicing and anti icing system. Aircraft Instruments: Flight instruments and navigation instruments – accelerometers, air speed indicators – mach meters – altimeters - gyroscopic instruments– principles and operation – study of various types of engine instruments – tachometers – temperature gauges – pressure gauge – operation and principles.

AVIONICS

Introduction to Avionics: Need for avionics in civil and military aircraft and space systems – integrated avionics and weapon systems – typical avionics subsystems, design, technologies – Introduction to digital computer and memories. Digital Avionics Architecture: Avionics system architecture – data buses – MIL-STD-1553B – ARINC – 420 – ARINC – 629. Flight Decks and Cockpits: Control and display technologies: CRT, LED, LCD, EL and plasma panel – Touch screen – Direct voice input (DVI) – Civil and Military Cockpits: MFDS, HUD, MFK, HOTAS. Introduction to Navigation Systems: Radio navigation – ADF, DME, VOR, LORAN, DECCA, OMEGA, ILS, MLS – Inertial Navigation Systems (INS) – Inertial sensors, INS block diagram – Satellite navigation systems – GPS. Air Data Systems and Auto Pilot: Air data quantities – Altitude, Air speed, Vertical speed, Mach Number, Total air temperature, Mach warning, Altitude warning – Auto pilot – Basic principles, Longitudinal and lateral auto pilot.

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