DEPARTMENT OF AEROSPACE ENGINEERING

ELECTIVE COURSES - 01.01.2017

DEPARTMENT OF AEROSPACE ENGINEERING, IIT MADRAS

ELECTIVES

AS 5300 Physical Gas Dynamics 3003

Introductory Kinetic theory (definition of pressure and temperature from microscopic viewpoint, mean free path transport processes). Equilibrium kinetic theory (Maxwell's distribution, collision rate). Chemical equilibrium (Effective collision rate, Law of mass action, activation energy). Chemical thermodynamics (Gibb's relations, Mixture of perfect gases, van't Hoff's relation). Statistical thermodynamics (Macroscopic and microscopic descriptions, Quantum energy states, energy modes of molecules, Boltzman's relation, contribution of internal structure). Equilibrium gas properties (Ideally dissociating gas, Ionisation equilibrium, Collision cross sections). Flow with translational non-equilibrium (Bhatnagar-Gross-Krook model for translational non-equilibrium, Chapman-Enskog solution, Transport properties as nonequilibrium phonomena, Linearised Couette flow).

AS 5310 Object Oriented Programming for Scientists and Engineers 3003

An overview of object programming (OOP). Introduction to C++. Essentials of OOP – data encapsulation,overloading, inheritance.User defined data types. Input/output. Code reusability. Templates – use of templates to write reusable code.

OOP applications to numerical analysis – find epsilon of the machine, interval analysis and interval class. A matrix class. Solutions to differential equations – ODEs and PDEs using grid point class, finite volume class and finite element class. Simple graphics and visualization. Random number generators, Monte-Carlo methods, Random walk, discrete event simulation.

Object oriented design and its implications to problem formulation and solution.

AS 5320 Boundary Layer Theory 3003

Prandtl's approximation of Navier-Stokes equations. Blasius solution for a flat plate integral momentum equation. Karman – Polhausen method. Walz-method. Unsteady boundary layer. Introduction to thermal and turbulent boundary layers.

AS 5330 Computational Aerodynamics 3003

Introduction to computation methods. Examples : Method of steepest descent, numerical integration, interpolation, etc. Relaxation methods applied to subsonic and

transonic flows. Method of singularities; Vortex lattice methods. Variational methods. Time-dependent methods. Treatment of shocks. Introduction to boundary-layer calculations. Introduction to finite-element method and its applications to fluid flows.

AS 5340 Advanced Flight Mechanics 3003

Optimization of airplane performance : Instantaneous and integral performance problems and conditions for their optima. Optimization of range and climb performance; Energy height method.

Longitudinal and lateral dynamic stability. Response of airplane to deflection of controls, gust and turbulence. Stability with automatic control. Role of analog computers and simulators in stability analysis. Stability and control after stall. Recent trends.

AS 5350 Transonic Aerodynamics 3003

Some concepts and properties of transonic flow, Fundamental equations, similarity rule, flow in the throat of convergent-divergent nozzle, consideration of shock on an aerofoil. Methods of transonic flow calculations: Guderley profile, exact solutions by hodograph theory, parabolic method, integral method, method of Murman and Cole. Equivalence theorem and area rule.

AS 5360 Advanced Aerodynamics 3003

Thin and thick aerofoils in incompressible flow. Limitations of lifting line theory, concepts of extended lifting line theory, Lifting surface theory. Interaction problems. Small perturbation equations in compressible flows: Pradtl-Glauert and Goethert rules. Ackeret's supersonic airfoil theory. Wings of finite span in incompressible and compressible flows. Aerodynamics of the fuselage and wing fuselage combination.

AS 5370 Helicopter Aerodynamics 3003

Introduction. Rotor aerodynamics : Momentum theory for vertical and forward flight, ground effect. Rotor mechanics: Blade motion, pitch, flap and lead-lag. Performance: Hover ceilings, steady vertical and level flight, climb, range, endurance, autorotation.

AS 5375 Dynamics and Control of Rotorcraft 3003

Numerical techniques: periodic shooting, Floquet theory Helicopter dynamics: aeromechanical instabilities: ground resonance, air resonance Flight dynamics and control: Trim algorithm, Inflow modelling, flight dynamics, periodic control Applications to Unmanned aerial vehicle: Quad rotor modelling, System architecture for control system, Guidance.

Dynamics and control of rotorcraft

AS 5380 Flight Testing and Performance Reduction 3003

Basic definitions. Airspeed, altitude and temperature measuring systems, errors and calibration. Measurement of power of internal combustion engines, determination of corrected power. Measurement/estimation of thrust of Turbojet engines. Useful thrust and s.h.p of turboprop. Data acquisition systems. Flight test techniques for evaluation of performance and stability of aircraft with piston and jet engines. Performance reduction methods. Reduction of take-off and landing performance.

AS 5390 Numerical Methods in Gas Dynamics 3003

General Introduction. The Gudonov scheme. BVLR method. Method of characteristics in two- and three-dimensional flows. Method of integral relations Blunt body problem. Particle in cell method.

AS 5400 Theory and Computation of Vortex Dominated Flows 3003

An introduction to vortex flows – vortices in everyday life – vortices in tea cup, the tornado, vortex rings. Geometrical and Kinematical preliminaries. Laws of vortex motion. Stretching, viscous diffusion and creation of vorticity. Vortex momentum. Dynamics of Vortex filaments. Dynamics of point vortices in two dimensions – The Karman Vortex street. Evolution and roll up of open and closed vortex sheets. Birkhoff-Rott equation. Kelvin-Helmholtz instability. Kaden's spiral.

Dynamics of vortex patches. Contour dynamics. Starting vortex behind an airfoil. Formation of vortex rings. Structure of the trailing vortex behind the wing and vortex breakdown. Computation of vortex merging and roll-up using the vortex blob method. Computation of incompressible, unsteady flows using the random vortex method. Fast vortex methods. Introduction to computation of 3 dimensional vortex flows.

AS 5410 Grid Generation 3003

An introduction to tensor calculus, Transformation of coordinates, General principles of grid generation, structured grids in two and three dimensions: Algebraic grid generation. Differential equation based grid generation: Elliptic, Parabolic, Hyperbolic grid generation. Cartesian grids, Unstructured Grid generation – various algorithms. Grid clustering, Grid refinement, Adaptive grids, Moving grids algorithms, CAD interface to grid generators, Techniques for complex and or large problems: Multi block methods, grid generation for distributed problem solving.

AS 5420 Introduction to CFD 3003

Introduction to numerical methods - machine epsilon, numerical differentiation and integration. Advection and diffusion by wave equation, heat equation and Laplace equation. Properties of the solutions. Discretization schemes for the one dimensional first order wave equation. Dissipation, Dispersion and stability of such schemes. Simple extension to Quasi-One-Dimensional Euler equations and Full Euler equations. Solution to heat equation. Time marching schemes-ADI, LU approximate factorization schemes. Solution to Laplace equation-Point interactive technique. Properties of the solution. Introduction to grid generation-algebraic grids, elliptic grids. Applications to flow problems.

AS 5430 Stability of Shear Flows 3003

Introduction to steady flows, their stability and bifurcations. Kelvin-Helmholtz instability. Stability of Parallel Shear flows. Orr-Sommerfeld Problem. Temporal Stability of Parallel Shear Flows. Non-linear Stability. Stability of Boundary Layer Flows. Transition. Chaos and Turbulence.

AS 5440 Hydrodynamic Stability, transition and Flow control 3003

Introduction to linear instability and transition. Recent developments in instability methods; transient growths, global analysis, optimization and feedback mechanisms. Routes to turbulence, factors affecting different mechanisms and re-laminarization. Methods to achieve transition delay, lift augmentation, separation prevention, turbulence suppression, noise abatement and other flow control strategies. Transition control: Wall heating and cooling, wall motion, suction and blowing etc. Separation control: Velocity profile modifiers, shaping, heat transfer, turbulators, etc. Drag reduction: reduction of near-wall momentum, Toms effect, etc. Recent developments in flow control.

AS 5450 Wind Turbines 3003

Wind data analysis, probability distribution functions, wind energy production estimates. Momentum theory, induction factor, coefficient of power, Betz limit, Rotor performance, wind turbine wake, effects of swirl, review of basic airfoil aerodynamics, Airfoils, blade shapes. Blade element momentum theory, effects of tip loss, inflow variation, concepts of dynamic wake.

Basics of rotor dynamics, flapping equation with and without hinge offset, flapping equation with gravity, effects of yaw, introduction to stability and control. Basics of fatigue analysis. Effects of Turbulence, autocorrelation and cross-correlation, vonKarman spectrum, Taylor's frozen turbulence hypothesis, turbulence seen in rotating frame, turbulence loading on wind turbines. Unsteady Aerodynamics, Theodorsen function, dynamic stall Introduction to acoustics, design aspects.

AS 5460 Finite Volume Methods for Hyperbolic PDEs 3003

Classification of PDEs – elliptic, hyperbolic and parabolic; discrete representation of PDE using Finite difference Method: accuracy, consistency and stability of discretized PDE; dissipation and dispersion errors, stability analysis using von Neumann and matrix methods; finite volume method: basic concept;
Linear model equation: 1-D (wave) advection equation – exact solution, notion of wave speed and characteristic, numerical solution using FDM and FVM; upwinding methods
Non-linear model equation: Burgers' equation – numerical solution to Burgers' equation; Godunov's scheme; shocks and centered expansions; shock speed

System of linear equations: linear acoustics equations (1D), wave speeds / Eigen values and Eigen vectors, characteristic variables, Riemann problem and its solution, upwinding methods for system of equations;

System of non-linear equations: Euler equations, conservation and quasi-linear form, flux Jacobian matrix, Eigen values and Eigen vectors, characteristic variables;
Flux reconstruction methods for the Euler equation: flux- vector splitting schemes – van Leer, AUSM and LDFSS schemes; flux difference splitting scheme: Roe's method;
Higher order interface state reconstruction: MUSCL scheme with limiters;
Higher order time integration: Runge-Kutta methods;

AS 5470 Unsteady Aerodynamics of Moving Bodies 3003

Airfoils and wings in steady motion. Analytical methods for the unsteady aerodynamic behaviour of oscillating airfoils and wings. 2D unsteady thin airfoil theory. 3D unsteady wing theory. Airfoils and wings undergoing arbitrary motion. Gust. Time domain and frequency domain analysis of unsteady flows. Kelvin impulse and apparent mass concept in unsteady flows. Aerodynamics of flapping and hovering bio-mimetic

flights. Numerical techniques for unsteady potential flows. Unsteady flow-field of natural invertebrates and aquatic animals and flapping-type MAVs. Discussion on 3D and Re effects.

AS 5540 Space Flight Dynamics 3003

Conic Sections, Kepler's Laws, Fundamentals of orbits, co-ordinate systems and transformations, Governing equations for two body system, Orbit representation in 3D, Keplerian orbital elements, Dynamics of rotating frames, Orbit determination – Laplace, Gauss, Lambert, and Gibbs methods, Orbit Perturbations, Orbit Manoeuvres, Restricted circular 3-body problem, Interplanetary mission design.

AS 5545 Dynamic and Control of Space Craft

To introduce students to spacecraft attitude dynamics, rigid and multi-body dynamic equations, spacecraft stabilization concepts, attitude determination and control design strategies etc.

Satellite dynamics as rigid body: Fundamentals of Equations of Rigid spacecraft Motion, using Newton, Lagrange and Hamiltonian approaches. Types of Satellite Stabilizations, Spin, gravity-gradient, Dual-spin, Momentum biased, zero-momentum biased concepts; Dynamics and control of spinning spacecraft, characteristics of spin dynamics —stability, precession and nutation; Dual spin concept and equations of motion. Dynamics and stability of bias-momentum and zero-momentum three-axis stabilized spacecraft; spacecraft dynamics as rigid multi-body with articulated antennas, rotating solar panels etc., methods of dynamical analysis. Modeling spacecraft perturbations / disturbance torques in orbit and torque-free attitude motion.

Attitude Determination Methods: Attitude sensors, sun, earth, star sensors, magnetometers, magneto-torquers modeling, sensor characteristics, Geo-magnetic field model and usage. Spin Stabilized spacecraft systems - methods using sun and earth sensor o/ps / magnetometer o/ps. - Momentum and 3-axis Stabilized systems - methods using sun, earth, star & magnetometer o/ps. Attitude Determination using vector measurements, TRIAD, QUEST Algorithm for vector based measurements, Wahba and Mortari's methods. Vector measurements from Star Sensor, Star catalog generation, Mission star catalogs, Star Identification Techniques.

Control of Spacecrafts: spin-axis attitude and control. Control using dual-spin concept, problems and solutions, control using two momentum wheels configurations, with magnets and thrusters. Design of control system for three-axis stabilized spacecraft: using reaction wheels, thrusters etc. Estimation of spacecraft attitude states from sensor measurements, Kalman filters, mechanization of Kalman Filters for attitude estimation, PI, PID, PD controllers, spacecraft attitude maneuvers design, guidance

aspects, rest-to-rest attitude maneuvers, rate-to-rest and rest-to-rate attitude maneuvers.

AS 5550 Aerospace Systems Control and Estimation 3003

Frequency domain and state space technique; control law design using Nyquist diagrams and Bode plots; state feedback, state estimation, design of dynamic control laws; elementary analysis of non-linearities and their impact on control design, basic applications of control theory to aerospace systems, navigation, guidance.

AS 5560 Dynamical Systems Stability and Bifurcations 3003

Introduction to dynamical systems, existence and uniqueness of solutions, concepts of steady states and stability, stability theorem,
1-dimensional parameterized systems, fixed points, stability, and bifurcations, normal forms
2-dimensional parameterized systems, nullclines, index theory, fixed points, periodic attractor, stability, and bifurcations, normal forms, Poincare'-Bendixson theorem higher-dimensional systems, fixed points, stability, and bifurcations, chaos via bifurcations of steady states, periodic attractor, strange attractor, 2-dim iterative maps for 3-dim systems and their treatment
Iterative maps representing dynamical systems, periodic solutions, stability, Floquet multiplier, fractal dimensions

AS 5610 Rocket Propulsion 3003

Chemical rocket performance: Thermochemical calculations. Liquid propellant rockets: Droplet combustion, feed system and ignition, injector design, combustion chamber geometry and cooling, nozzle design, thrust vector control. Solid propellant rockets: Combustion mechanisms, grain design, two phase flow, case fabrication problems. Combustion instability.

AS 5615 Spacecraft Electric Propulsion 3003

Basic orbital mechanics and astrodynamics, Introduction to rocket propulsion and rocket performance, comparison of chemical rockets and electrical rockets, introduction to electrodynamics, kinetic theory and non-equilibrium flows, basic plasma physics, electro-thermal propulsion (arcjets and resistojets), electrostatic propulsion (Hall thrusters, ion thrusters),electromagnetic propulsion (MPD thrusters, PPT thrusters)

AS 5620 Theory and Design of Gas Turbines 3003

Introduction to aircraft gas turbines. Non-rotating components: Aero thermodynamics of inlets, combustors and nozzles. Rotating components: Exchange of energy between rotor and fluid. Euler equation, stage performance analysis. Multistage compressors and turbines. Centrifugal and axial compressors and axial turbines. Stall and surge problems of compressors. Structural and cooling problems of turbine blades.

AS 5630 Performance of Gas Turbines 3003

Typical engine performance. Non-dimensional representation. Off design performance estimation of turbojets. Components characteristics and component matching: Equilibrium operation. Principles of controls and instruments. Noise suppression, starting and ignition, fire and ice protection.

AS 5640 Combustion, Explosion and Detonation 3003

Review of reaction kinetics. Flame theories for premixed and diffusion flames. Flame stabilization and combustion instabilities. Solid and liquid propellant combustion. Erosive burning of solid propellant grains. Explosion theories. Detonation theory. Deflagration to detonation transition.

AS 5650 Multiphase Flow 3003

Historical review: Need for such a study, various flow regimes, fundamental notations, definitions and experimental correlations. Basic relations: Homogeneous, separated and continuum mixture approaches for governing equation derivations.

Basic parameters and interactions. Transport properties and boundary condition. One-dimensional waves: Continuity and dynamic waves. Pipe flow sedimentary flow, boundary layer motion, flow over body and flat plates, cyclone separators, fluidized beds, gasification and combustion of coal, pneumatic transporters.

AS 5660 Hypersonic Airbreathing Propulsion 3003

Introduction to hypersonic flight in the atmosphere and the propulsion requirements thereto. Thermodynamic, fluid mechanical, gas dynamic, and thermochemical background for supersonic combustion ramjets. Overall performance considerations of hypersonic propulsion systems and the need for supersonic combustion. Hypersonic airbreathing engine performance analysis. Component performance in inlets, combustors and exhaust nozzles. Other hypersonic airbreathing propulsion concepts, such as the detonation wave engines.

AS 5670 Transport Processes in Reacting Flows 3003

Principles of heat transfer: conduction, convection, and radiation. Mass and momentum transfer: elements of mass diffusion and boundary layer theory. Chemical kinetics and equilibrium chemistry. Fundamentals of combustion and flame: premixed flame speed, Burke-Schumann analysis of diffusion flames, and droplet combustion.

AS 5680 High Temperature Gas Dynamics 3003

Review of equilibrium gas properties, non-equilibrium and non-equilibrium kinetic theory. Equilibrium flow (Steady shocks, nozzle flow, Prandtl-Meyer flow, Frozen flow) Vibrational and Chemical rate processes (Vibrational rate equation, chemical rate equation, local relaxation times, small departures from equilibrium). Flow with Vibrational and chemical non-equilibrium (Equilibrium and frozen flow, non-linear equations, acoustic equations, speed of sound, sound propagation, small departures from uniform flow, linearised normal shock wave, dispersed shock wave, nozzle flow, MOC). Flow with translational non-equilibrium (transport properties, Bulk viscosity, structure of shock wave, linearised Couette flow). Radiative transfer in gases (Equation of radiative transfer, radiative equilibrium, radiation-solid surface interaction, Emission and absorption of radiation). Flow with radiative non-equilibrium (Basic non-linear equations, grey gas, 1D equations, normal shock wave).

AS 5690 Radiation Heat Transfer 3003

Physics of thermal radiation, methods for evaluation of view factor, radiation exchange between gray, diffuse and partly specular solid surfaces, basic equations for radiation heat transfer in absorbing, emitting and scattering media, radiative properties of molecular gaases, spectral models for radiative heat transfer (Narrow Band models, Wide Band models), approximate methods for radiation heat transfer in participating media (optically thick limit, optically thin limit, P_N approximation, S_N approximation), treatment of non gray gases. Radiation heat transfer application in space propulsion,microgravity combustion and re-entry problems.

AS 5810 Theories of Modern Plate Structures 3003

Variational formulation of the classical theory of isotropic plates and counterparts for anisotropic, sandwich and layered plates and plates made up of functionally graded or piezoelectric materials. Combined bending and stretching.

Shear Deformation Theories: First-order Theory and Higher-order Theories based on global approximation and discrete layer approaches. Three-dimensional analysis.

Comparison of various theories for simple rectangular plate/strip problems.

AS 5820 Analysis of Plates and Shells 3003

Classical bending theory of thin flat rectangular and circular plates and with various edge conditions and loading.

Membrane and bending theories of thin shells of revolution. Analysis of circular cylindrical shells.

AS 5830 Approximate Methods in Structural Analysis 3003

Principle of minimum total potential. Principle of minimum complementary potential. Rayleigh-Ritz, Galerkin, Collocation methods, etc. Finite-difference method. Finite element method. Computer based solutions to examples including field problems, nonlinear problems.

AS 5840 Thermal Stress Analysis 3003

The basic equations of two-dimensional and three-dimensional thermoelasticity. Application of two-dimensional problems of elasticity, thermal stresses in beams, membranes and plates. Thermal buckling.

AS 5850 Finite Element Analysis 3003

Matrix methods of analysis: Stiffness and flexibility. Truss, frame and grid-work examples. Finite elements: Discretisation of the continuum, analysis of plane and axisymmetric problems, isoparametric concepts and applications, bending elements. Computer implementation.

AS 5860 Composite Structures 3003

Review of material properties and macro mechanics of composites. Anisotropic theory of elasticity. Plate anisotropic elasticity problems. Analysis of rotating disc. Stress analysis of anisotropic beams, columns, plates and shells. Classical and improved theories of laminated structures. Comparison of the structural behaviour of composite structures with conventional isotropic structure. Vibration and stability analysis. Analysis of wave propagation through composite media. Stress concentration around holes and cut-outs. Stress analysis of bolted and bonded joints. Finite element method of analysis. Analysis of sandwich structures.

AS 5870 Energy Methods in Structural Analysis 3003

The variational principle and the derivation of the governing equations of static and dynamic systems. Different energy methods: Rayleigh-Ritz, Galerkin etc. Application: Problems of stress analysis, determination of deflection in determinate and indeterminate structures, stability and vibrations of beams, columns and plates of constant and varying cross-sectional area.

AS 5880 Mechanics of Damage Tolerance 3003

Basics of Damage Tolerance: Strength vs. Damage Tolerance, Historic introduction and Molecular Interpretation.

Mathematical preliminaries: Vectors and Tensors, Complex Variables & Functions, Taylor's and Laurent's Series Expansions, Poles & Residues, Contour Integration.

Review of Elasticity: Stress & Strain, Equilibrium, Elasticity, Plasticity and Yield Criteria, Strain Energy, Plane Stress and Plane Strain, Solution methods, Airy stress functions, Complex potentials.

Stress Analysis of Cracked Bodies: Stress Concentration in Circular and Elliptic Holes, Stress Intensity Factor, Fracture Modes, Other Analytical, Numerical and Experimental methods.

Energy Concepts: Strain Energy Release Rate, J Integral, Virtual Crack Closure, Equivalence of Energy and Stress approaches.

AS 5900 Elasticity 3003

Field equations of three dimensional elasticity; Theory of stress and strain, Generalised Hooke's law, compatibility conditions, boundary conditions.

AS 5930 Elastic Stability 3003

Stability of columns: Closed and open sections, flexural, torsional and combined. Inelastic buckling. Buckling of flat and stiffened plates. Approximate solutions. Rayleigh-Ritz, Galerkin, finite-difference and finite element methods to determine buckling loads. Crippling of thin-walled sections. Use of master column charts.

Introduction to post-buckling of columns and plates, snap buckling of shallow arches and shells.

AS 5950 Continuum Mechanics 3003

Tensor Algebra, tensor Calculus, Kinematics of Deformation and Motion, Fundamental Laws and Equations (Conservation of mass, conservation of momentum, conservation of energy, restrictions of elastic materials by second law of thermodynamics, constitutive equations), Linear Elasticity, Kinematics of Fluid Motion, Classical Fluids, Linear Visco-elasticity, Non-linear Elasticity.

AS 5960 Advanced Strength of Materials 3003

Analysis of indeterminate beams: Clapeyron's equation for continuous beams – Analysis of frames and rings – Analysis of curved beams – Composite beams. Wide beams – Torsion of noncircular solid and thin-walled crosssections, Warping function.

AS 5970 Structural Dynamics and Aeroelasticity 3003

Review of vibration of discrete and continuous systems-Aspects of nonlinear dynamical system behaviour and solution techniques, some examples like Vander Pol oscillator, Duffing and Mathieu systems – Introduction to some advanced topics like coupled oscillations, rotating beams, random vibrations, unsteady aerodynamics.

Static aeroelasticity, wind tunnel models, divergence instability and aileron reversal – Aeroelastic flutter, stability characteristics and aeroelastic analysis of a typical section, classical flutter analysis and engineering solutions – introduction to nonlinear aeroelasticity.

AS 5980 Contacts Mechanics and Tribology 3003

Introduction to Friction and Wear, History of Tribology. Elastic Contacts: Elasticity Equations, Hertzian contacts, Integral Equation Methods. Plasticity: Yield Criteria, Hardness Testing, Shakedown Criteria. Surface Topography: Statistical Characterization, Rough Surface Contact. Friction: Friction Laws, Frictional Contact and Fretting, Frictional Heating. Wear:Wear Models/Maps,Experimental Characterization of Wear. Lubrication: Reynolds Equation, Elasto-hydrodynamic Lubrication.

AS 5990 Micromechanics 3003

Basic results in Micromechanics: review of solid mechanics/elasticity, eigenstrains, Eshelby's equivalence principle, elasticity solution for the Eshelby inclusion problem, Hill-Mandel homogenization theory, Proof of the Hill-Mandel lemma.

Effective properties of composites: effective elastic properties of heterogeneous media, bounds on effective modulii: Voigt, Reuss and Hashin-Shtrikman bounds, self-consistent and Mori-Tanaka averaging methods, Comparison of different averaging methods, composite cylinders and composite spheres models for effective modulii, computational methods for periodic microstructures.

Elements of nanomechanics: types of defects in crystals, Fick's laws of diffusion, elastic fields of dislocations, introduction to discrete methods in solid mechanics, molecular dynamics and discrete dislocation dynamics simulation methods

AS 6000 Basic Concepts in Aerospace Engineering 003

Classification of Airplanes, Principles of flight, Flight Controls, Basic Instruments and aircraft systems, Helicopters.
Introduction to Wing and fuselage construction: functions of structural components; Structural idealization; Shear centre; Bending, shear and torsion of closed and open tubes; Multi-cell tubes; Brief discussion of buckling and postbuckling.

Basic equations of fluid flow: Generalized conservation law - integral form; Conservation of mass, momentum, energy - specialization to potential flow.
Thin airfoil theory, effect of viscosity, finite wings, Prandtl's lifting line theory. Area rule, sweep; Aircraft stability and control - maneuvers, longitudinal stability.

One-dimensional isentropic flow, Mach wave, flow with shocks, heat, and friction, oblique shocks, Prandtl-Meyer expansion, two-dimensional linearized subsonic flow.
Introduction to air breathing engines: piston engine + Propeller, turbojet, turboprop, turbofan, ramjet, scram jet, and pulse jet. Introduction to non-air breathing engines: Solid propellant rockets, liquid propellant rockets, hybrid propellant rockets and other rockets. Introduction to hybrid engines: ducted ram rocket, solid fuel ram jet.

AS 6010 Hypersonic Flow Theory 3003

Introduction, Basic considerations and definitions. Hypersonic flight paths. Inviscid hypersonic flow theory: Shock expansion method, Surface inclination methods. Small disturbance equations and approximate methods. Similarity laws: Exact methods, Method of characteristics, Blunt body problem and solution. Computational methods. Introduction to viscous hypersonic flows.

AS 6015 Aerodynamics of Missiles and Launch Vehicles 3003

Introduction to missiles and launch vehicles, bodies of revolution, non-circular shapes, lifting surfaces, low Aspect Ratio characteristics,wing – body – tail interference,

prediction of overall characteristics of body dominated configurations and lifting surface dominated configurations, high angle of attack aerodynamics, dynamic derivatives, boundary layer, shock wave – boundary layer interactions, aerodynamic heating, intake aerodynamics, engine-airframe integration, airframe flexibility effects on aerodynamics. Stage separation dynamics. Configuration design methodology of tactical missiles. Design methodology of multistage vehicles.

AS 6020 Introduction to Turbulent Flows and their Predictions 3003

Basic features of turbulent flows. Ways of describing turbulent flows: Statistical aspects, correlation, spectrum, conditional sampling. Experimental methods: Hot wire anemometer and Laser Doppler anemometer. Equations for compressible turbulent flows. Experimental data on turbulent intensities in some turbulent flows.

Prediction of turbulent flows: Statistical theory and its limitations, Integral methods, turbulence modelling, mixing length hypothesis, one-equation and two-equation models, modelling of Reynolds stress. Computer codes and comparison between experimental data and predictions.

AS 6030 Experimental Methods in Aero/Gas Dynamics 3014

High speed wind tunnels. Special purpose tunnels. Shock tubes, Ballistic ranges. Schlieren, shadowgraph, interferometry. Laser applications. Radiation and spectroscopy. Heat transfer measurements. Analogy techniques. Mechanical vibrations : Accelerometers, frequency analysis.

AS 6040 Turbulent Flows and their computation 3003

1. Tensors functions and analysis
2. Random data analysis
3. Homogeneous Isotropic Turbulence
4. Homogeneous Anisotropic turbulence
5. Spectral Analysis and Navier Stokes Equations
6. Turbulence Modeling
7. Second order (Reynolds Stress) Modeling
8. DNS of Turbulent Flows
9. LES of Turbulent Flows
10. Coherent Structures in Turbulent Flows
11. Dynamical Systems approach to Turbulent Flows

AS 6050 Dynamic Fluid Structure Interaction 3003

Derivation of governing equations; time domain and frequency domain analysis of generic dynamical systems. Introduction to nonlinear dynamical systems; stability analysis and bifurcations; supercritical and subcritical behavior. Stability of periodic systems. Numerical techniques to solve nonlinear systems; introduction to chaos. Quasi-steady and unsteady modeling of flows. Flow induced oscilation problems; bluff body wake instability. Modeling vortex induced vibrations in: forced systems, fluid-elastic systems. Concept of added mass. Vortex induced vibration in 3D and non-circular cross-sections. Flutter; rain and wind induced vibrations. Canonical gust models. Introduction to structural vibration under deterministic and random wind models.

AS 6060 Shockwave Dynamics 3003

Unsteady 1-D flows: Governing equations for non-stationary flows, Riemann invariants, finite amplitude waves, rarefaction and compression waves.
Shock reflections and interactions: Background-Regular and Mach reflections – two and three shock theories – shock polar presentation of the flow fields. Transition criteria for regular to irregular reflections (RR to IR). Typical cases of steady reflections. Mach reflections (MR) - hysteresis in RR-MR transitions. Shock reflections in pseudo-steady and unsteady flows– *von Neumann paradox*, shock diffraction, shock reflections on non-straight surfaces, shock focusing. Shock intersections and the *Edney classification* of shock-shock interferences.
Shock tube flows: Wave systems in a shock tube - hot and cold gas regions, reflection of shock and rarefaction waves, collision of shockwaves, collision of rarefaction and shockwaves. Open end flows-spherical blast waves, various shock structures. Contact discontinuities-refraction of shock and rarefaction waves at a contact surface, Ritchmeyer–Meshcov instability.
Shock-boundary layer interactions(SBLI): Physical background - structure of boundary layer flow-boundary layer response to a rapid pressure variation. Basic SBLI in 2-D flows - boundary layer–shock pressure jump competition. SBLI with and without separation.

AS 6320 Acoustic Instabilities in Aerospace Propulsion 3003

Introduction to Acoustics ; Derivation of the wave equation in both cartesian and polar co-ordinates, applications to problems. Fundamentals of Combustion Instability; Basic principles, instability in solid and liquid rockets and ramjets, passive and active control of combustion instability, pulse combustors. Theoretical Analysis of Combustion Instability. Measurement techniques.

AS 6330 Aeroacoustics 3003

Introduction to Acoustics: Derivation of the governing equations, Lighthill's analogy. Aerodynamic sound in unbounded flows; The Ffowcs Williams – Hawkings equation, vorticity and entropy as sources of sound, sound generation in a fluid with rigid and flexible boundaries, vortex-sound theory of Powell. Aeroacoustics of internal flows; Waves in pipes, Howe's formulation, orifice flows, musical aeroacoustics. Resonant and unstable systems; cavity resonances, edge tones, combustion instabilities.

AS 6340 Combustion and Flow Diagnostics 3003

Fundamentals of digital data acquisition, Dynamic transducers for transient measurements; Fundamentals of digital image processing, Lasers and laser safety; Principle and application of Particle Image Velocimetry (PIV) and Laser Doppler Velocimetry (LDV); Fundamentals of spectroscopy; Rayleigh scattering; Raman Scaterring, Laser Induced Fluorescence, and their application in species concentration and temperature measurements. Digital Background oriented Schileren; Optical patternation for spray diagnostics

AS 6342 Spectroscopic Reactive Flow Diagnostics 3003

Introduction to electromagnetic spectrum, review of quantum mechanics concepts. Absorption, emission, fluorescence, scattering processes. Planck's law, Beer's law, spectra and spectral lines, optical density; line position, line strengths and line shapes of spectral transitions; broadening mechanisms (natural, collision, Doppler, stark, instrument), line shape functions (Gaussian, Lorentzian, Voigt), line shifting mechanisms (pressure and Doppler shifts). Atomic and molecular spectra (diatomic & polyatomic); electric dipole moment (IR), induced polarization (Raman), elastic (Rayleigh) scattering; rotational (MW), vibrational (IR), ro-vibrational, electronic (UV & VIS) spectra; Rayleigh & Raman spectra. Quantitative emission and absorption, radiative transfer equation, spectral absorption coefficient, temperature dependence; pressure, temperature and species concentration measurements. Diagnostic techniques for gaseous flow and combustion: LIF, PLIF, Rayleigh scattering, spontaneous Raman scattering, coherent anti-Stokes Raman spectroscopy, cavity ring-down spectroscopy, laser absorption spectroscopy, TDLAS, LIBS, FTIR spectroscopy, LII. Spectroscopic softwares (HITRAN, LIFBASE).

AS 6510 Experimental Techniques in Structural Mechanics 3003

Strain gauges : Mechanical, electrical, acoustic, pneumatic and other types of strain gauges. Associated circuits for electrical resistance strain gauges.

Photo-elasticity : Two-dimensional photo-elasticity. Reflection polariscope, photo-stress coats.

Analogies : Membrane, electrical analogies. Transducers; Pick-ups to measure displacement, velocity, acceleration and forces.

AS 6520 Mathematics for Aerospace Engineers 3003

Linear Algebra including matrices, solution of linear system of equations, Eigenvalues and eigenvectors, Cayley-Hamilton Theorem. Analytic functions. Cauchy-Riemann equations and application to potential theory, Line integral, Cauchy integral theorem, Taylor' and Laurent' series, Residue theorem and applications. Conformal mapping and applications, Fourier Series, Laplace Transforms. Vector and Tensor Calculus, Review of first and higher order ODEs, Classification of PDEs, Laplace equation, heat and wave equations, classical and approximate solution techniques with applications to problems in aerospace engineering.

Review of basic Probability theory, Random variables, discrete and continuous distributions.

ID 5040 Engineering Plasticity 3 0 0 3

Phenomenon of plasticity, experimental facts, lumped parameter models, 1-D elasto-plastic problems - bending and torsion, three dimensional isotropic plasticity, yield criteria, flow rules, hardening laws, governing equations for small strain elasto-plasticity, integration algorithms, intro to finite deformation plasticity.

ID 6080 Impact Mechanics 3003

Rigid body impact: Low-speed impact of rigid bodies, collinear impact, Two dimensional impact.
Impact of deformable bodies: Hertz contact problem, Elasto-plastic analysis of contact region, Elastic wave propagation during impact
Material response under high strain rate: Review of popular material models used for materials undergoing high strain rate (Elasto-plastic models, Johnson Cook Models etc.)
Experimental methods for impact analysis: Drop hammer tests, Split Hopkinsons bar experiment
Numerical methods for impact analysis: FEM models for high impact simulation, Review of case studies of specific applications such as, Vehicle crash analysis and Bird impact analysis

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