Course details and Program modality for Web-enabled MTech in Aerospace Engineering at IIT Madras

Introduction

The Web-enabled MTech program *matches* the regular and fully residential program **totally** in its *requirements* and *rigor*. The student, while working, takes courses at IIT M on the Web in the evenings which are held in an interactive mode in virtual classrooms.

Lectures will be delivered on a high-speed dedicated video link between 5 and 7 pm. A typical course will meet about 150 minutes every week and spend another 50-100 minutes on problem solving, Q&A etc.

The degrees awarded are identical to the degrees awarded to the regular students at IIT M in a residential mode. The details of the degrees awarded and the course-plan (such as core and additional courses for each degree) are contained in Annexure I & 2.

Program Module

This letter of Acceptance of Offer is applicable to the online M.Tech Program in Aerospace Engineering at IIT Madras for the batch commencing in the academic year _________.

i)	Program Title	: **M.Tech in Aerospace Engineering**
ii)	Duration	: 3 years
iii)	Semester	: Three sessions a year (Trimester scheme)
iv)	Program Courses	: Core courses (six) – I year Additional courses (five) – II year Project work – III year
v)	Program Schedule	: Batch commencing August ___________
vi)	Program Mode	: Online

vii) Course details and program modality are detailed in **Annexure-I** and syllabi of courses in **Annexure 2**

viii) Attendance of the participants to be recorded during the program.

ix) After completion of the program, a Degree Certificate to be awarded to successful students by IIT Madras.

Annexure-1

Program Schedule

- Program to begin in August along with the other MTech programs
- Three sessions (trimesters) in a year with each session lasting for about 16 weeks
- Maximum of two courses per trimester
- The number of lecture hours per course will be as dictated by the credit requirements.
- The videos of lectures are made available to the students for offline viewing.
- Course examination will be conducted at online/at designated centers decided by IITM and answer papers will be evaluated by IITM

- Grading policies as per IITM MTech ordinances
- First two years for course work (11 courses over 6 trimesters). Last year for the project

Infrastructure Required

- High bandwidth internet connection of at least 2 Mbps per active class to be provided at all the centers where the candidates are present.

Eligibility of the candidates: IIT Madras will have a test/interview on basic mathematics, fluid mechanics, strength of materials and thermodynamics to select the students. The candidates should possess Bachelor's degree in Aerospace/Civil/Chemical/Computer Science/Electrical/Mechanical/Metallurgical/Naval Architecture OR Master's degree in Physics/Mathematics/Chemistry. The applications of the candidates should be forwarded and routed through the parent industry/defense unit.

Project Work

- Both IIT M and the parent industry/defense unit will work together in selecting the appropriate student projects of interest/ relevance to unit and fine-tuning the scope of the project work.
- Project work will be carried out at industry/unit under the guidance of the someone whose academic qualification shall be MTech or higher.
- If IIT M guidance is required, separate costing need to be evaluated depending on the facility usage and consultancy time of the mentor.
- Project will be of one year duration and the student, and the guide(s) will have frequent virtual meetings for remote guidance, evaluation, and criticism.
- Guides are to be finalized no later than the end of the fourth trimester. This will ensure that some preliminary work (like literature review) can be started in the sixth trimester itself.
- There will be two progress review meetings, one each at the end of seventh and eighth trimesters. Final project evaluation will be at the end of 9th trimester (end of 3rd year).

Lab Courses: students will spend up to 2 weeks at IITM if lab course is required.

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Credit System at IIT M and expected efforts in the programme

- At IIT M, the courses are counted in terms of credits. Each credit implies 14 periods (50 min each) of effort (typically one period per week over 14 weeks), including evaluation.
- "**L**" implies lecture given by the faculty; "**T**" implies tutorials or problem solving; "**E**" implies extended tutorials under supervision of the teaching assistants; "**P**" implies lab/ practical; "**O**" implies effort expected from the students outside the class hours revising the material, working out additional problems etc. "**C**" is the sum total of all credits.
- Ex: Basic mathematics course in Annexure I is 3-1-1-0-6-11 credits, which means there will be 3 lectures a week, 2 tutorial periods a week and in addition, students are expected to spend 6 periods (5 hrs) preparing for the material every week for this course.

- Consequently, in each of the three trimesters, the student is taking 21 credits and hence is expected to spend 21 periods (17.5 hours) per week on the two courses.

Project Work in Year III

- Project work is worth 85 credits and hence each student is expected to put in 85*14*5/6 = about 1000 hours of work on the project.
- Since project work will be carried out in 3rd year, it amounts to about 20 hours per week for the project.
- Students are expected to finalize their guide by the end of the fifth trimester. This will ensure that some preliminary work (like literature review) can be started in the sixth trimester itself.

Detailed Curriculum and Credits for the program:

Year	Session	Course Name	Lecture	Tutorial	Extended Tut.	Afternoon Lab	Time to be spent outside class	Credits
I	1	Mathematics for Aero. Engineers	3	1	1	0	6	11
I	1	Aerodynamics & A/C performance	3	1	0	0	6	10
I	2	Compressible Fluid flows	3	1	0	0	6	10
I	2	Aerospace Structures	3	1	1	0	6	11
I	3	Aerospace Propulsion	3	1	0	0	6	10
I	3	Flight Mechanics	4	1	0	0	7	12
		Core theory Credits:	**19**	**6**	**2**	**0**	**37**	**64**
II	4 to 6	Electives courses (**Any 5**)	15	0	0	0	30	45
III		**Project**	0	0	0	0	88	88
		Total Credits:	**34**	**6**	**2**	**0**	**155**	**197**

Annexure -2

MTech Courses and syllabi

Core (introductory) subjects:
1. AS5010 - Aerodynamics and Aircraft Performance
Course Content:
Aerodynamics: Governing equations for fluid flows; incompressible flow and Bernoulli's equation; stream function and velocity potential; source, sink and doublet; non-lifting flow past a circular cylinder; circulation; lifting flow past a circular cylinder; Kutta-Joukowski theorem; flow past an airfoil: Kutta condition and Kelvin's starting vortex; thin airfoil theory; compressibility correction; finite wings: tip vortices, downwash and induced drag; Prandtl's lifting line theory; propeller theory. Aircraft Performance: Standard atmosphere; parts of an airplane; drag-divergence; area-rule; drag polar; steady flight: climb, range, endurance; accelerated flight; V-n diagram; takeoff and landing

2. AS5011 - Compressible Fluid Flows
Course Content:
Fluid Mechanics: Classification of fluid flow; Eulerian and Lagrangian viewpoints; streamlines, streaklines and pathlines; velocity gradient tensor; governing equations of fluid flow; Cauchy stress; boundary layers; Couette flow. Compressible Flows: Review of thermodynamics; isentropic flow relations; compressibility, speed of sound and Mach number; 1-D steady flow: adiabatic, frictionless flow with normal shock – Hugoniot curve, Fanno flow, Rayleigh flows; 2-D steady flows: flows with oblique shock, θ-β-M curve, Prandtl- Meyer expansion fans; 1-D unsteady flows: moving shock waves, shock tube; flow through CD nozzles: area-Mach relation, choked flow, underexpanded and over expanded nozzles; linearized subsonic and supersonic flows – Prandtl-Glauert relations

3. AS5020 - Aerospace Propulsion
Course Content: Classification of airbreathing engines, efficiencies of air breathing engines, engine performance of turbojet, turboprop, turbo shaft, turbofan and ramjet engines, thrust augmentation of turbojets and turbofan engines. Aerothermodynamics of non-rotating propulsion components such as intakes, combustor and nozzle. Basics of moving components (fans, compressors and turbines). Thrust equation and specific impulse, efficiencies of non-airbreathing engines vehicle acceleration, drag, gravity losses, multi-staging of rockets. Classification of chemical rockets, brief description of electrical rockets. Performance of solid, liquid and hybrid propellant rockets. Brief description of various components of solid, liquid and hybrid propellant rockets.

4. AS5030 - Aerospace Structures
Course Content: Determination of loads acting on major airplane components (wing, fuselage, tails). Analysis of wings. Shear centre. Bending and torsion of closed and open tubes. Multi-cell tubes. Columns and beam-columns. Bending and buckling of plates and sheet stringer combination. Analysis of fuselage. Learn about the main aircraft structural components, to introduce the concept of semi- monocoque construction in aircraft, discuss different loads acting on an aircraft, concept of airworthiness and generation of a safety-flight envelope (known as 'V-n' diagram). Modelling the components in terms of 1-D or 2-D structural elements. Analysis of thin-walled open and closed section beams under bending, shear and torsional loads. Bending and buckling of plates and sheet-stiffener combination. Structural idealization of wings and fuselage and preliminary analysis

5. AS5040 - Flight Mechanics
Course Content:

Review of rigid body dynamics: Derivation of full six degree of freedom equations of motion (translational, angular, and kinematic). Various reference axis systems – earth-fixed, body, stability, and wind axes. Equations of angular motions: Airplane pitch dynamics and longitudinal stability –trim, neutral point, static margin. Treatment of spacecraft attitude dynamics –disturbance torques, spin stabilization. Overview of satellite attitude determination and control techniques. Aircraft flight dynamics: Linearization of equations of motion about a steady flight condition. Aerodynamic derivatives. Aircraft dynamic modes and stability. Introduction to lateral and directional stability. Basics of orbital mechanics: Two body motion. Motion in elliptic, hyperbolic, and parabolic orbits. Keplerian orbital elements. Orbital maneuvers and transfer orbits.

6. AS6520 - Mathematics for Aerospace Engineers
Course Content: 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.

Additional Courses: (Any five)

ELECTIVES

AS 5300 Physical Gas Dynamics

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 phenomena, Linearised Couette flow).

AS 5310 Object Oriented Programming for Scientists and Engineers

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

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 5340 Advanced Flight Mechanics

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 5360 Advanced Aerodynamics

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

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

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

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 5420 Introduction to CFD

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 5460 Finite Volume Methods for Hyperbolic PDEs

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 5540 Space Flight Dynamics

A 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 5550 Aerospace Systems Control and Estimation

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

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

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 5620 Theory and Design of Gas Turbines

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 Turbine

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

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

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 5810 Theories of Modern Plate Structures

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

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

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 5850 Finite Element Analysis

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

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

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

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 5930 Elastic Stability

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 5970 Structural Dyamics and Aeroelasticity

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 6020 Incompressible Turbulent Flows

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

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 6060 Shockwave Dynamics

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 6340 Combustion and Flow Diagnostics

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 6510 Experimental Techniques in Structural Mechanics

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 5621 Design and Analysis of Turbomachines

Basic Principles of Turbomachines, Dimensional Analysis and Performance Characteristics 2D Cascade geometry and flow characteristics Meanline analysis and design of axial flow machines (compressors and turbines) Blade element theory, radial equilibrium, and 3D design concepts Hands on training to detect 3D flow features and post processing techniques in axial turbomachines. Estimating losses in turbomachines (due to transonic flows, secondary losses, mixing losses, tip leakage losses, etc). Stability orbits of axial compressors.

AS 6041 Advanced CFD - Eddy Resolving Methods

Governing Equations - Navier-Stokes Equations formulation in Physical and General coordinates. High order spatial and temporal schemes: Compact schemes and WENO schemes (for shock capturing), Brief overview of spectral Differencing methods, Skew-Symmetric Formulations and filtering schemes to enhance stability, Runge Kutta 4th order time integration. Hands on training on developing high order compressible finite difference solver with a) periodicity and b) wall boundary conditions (Predefined templates of Fortran subroutines will be provided) Accelerating applications - Brief overview of parallelizing procedures: Shared memory parallelism (OpenMP, GPUs) and Distributed memory parallelism (MPI) Post processing techniques - Reynolds stresses, Coherent vortices identification methods (Q-criterion, λ2-criterion), frequency spectra, autocorrelation, two point correlations (using Channel flow simulation) Overview of Realistic Inflow generation techniques, wall-models, Sub-grid scale models for LES, hybrid RANS-LES, Grid requirements with particular emphasis on Cost vs Accuracy. Engineering application of eddy resolving methods (ERMs) - Case studies on different components of Gas turbine engines.

AS 6242 Advanced Manufacturing Processes

Materials In modern Industries, Types of fabrication, Casting of complicated designs, forming (roll, high velocity hydro forming, high energy rate forming electromagnetic forming etc.), Welding and Forging techniques, Adv. techniques of material processing (STEM, EJT, ECG etc.), Micro-machining, Additive Manufacturing, Fabrication of cellular solids, composites (MMC, CMC and PMC) and functionally graded materials.

AS 5270 Materials and Processing Methods

Historical aspect and classification of materials, metals, alloys, ceramics & their properties, Composite Materials, functionally graded materials, and cellular solid, mechanical features of advanced materials in different sectors. Processing methods: Conventional (casting, forging etc.) and non-conventional fabrication techniques, Testing methods for advanced materials.

AS 5241 Measurement and Testing Methods

Mechanical measurement and importance of measurement from industrial perspective, Classification of measurement system, Conventional measurement methods - Sensors and transducers, displacement and acceleration; strain gages and extensometer; electrical resistance strain gages - measurement principle, error analysis and applications, Optical microscope, Electron Microscope, Laser based systems, Surface profilers, SEM, AFM; digital image correlation.

AE 5510 Security of Safety-Critical Systems

Introduction to safety-critical systems, system architecture of a typical safety-critical system, security vulnerabilities and attack vectors including side-channel attacks, different types of intrusion/attack detection systems, hardware-based and software-based attack mitigation strategies, attack-resilient system design, learning-based approaches for attack detection and mitigation, decision and game-theoretic approaches to security, randomisation and moving-target defence.

AE 5520 Verification of Cyber-Physical Systems

Brief introduction to automata and formal methods, modelling cyber-physical systems, requirements specification using a formal language, compositional reasoning, deductive verification, SMT-based model checking, reachability analysis, data-driven verification, stress testing of safety-critical systems, falsification techniques, runtime monitoring, contract-based design, verification of learning-based components.

AS 5211 Design of Subsonic Aircraft

Phases of aircraft design. Market analysis and mission statement. Historical data collection and initial weight estimation. Airfoil selection and wing design. Choice of thrust-to-weight ratio and wing loading. Drag estimation. Engine selection. Choice of fuselage parameters. Configuration and layout. Initial 3-view diagram. Weight and C.G. estimation. Landing gear and subsystems. Stability analysis and tail sizing. Performance evaluation. V-n diagram.

AS 5212 Design of Supersonic Aircraft

Philosophy of aircraft design. Need for high speed aircraft. Data collection of existing supersonic aircraft. Preliminary weight estimation. Aerodynamics of bodies in supersonic flows – supercritical and supersonic airfoils, drag divergence, wave drag, wing sweep, area rule. Selection of thrust-to-weight ratio and wing loading from performance requirements. Intake and nozzle design. Engines for supersonic flights. Configuration layout and preliminary 3-view diagram. Detailed weight estimate. Stability analysis and tail sizing. Performance evaluation. Noise and operational considerations.

AS 5213 Design of MAVs and UAVs

The design process and importance of design iterations. Mission specifications and requirements. Payload and sensors. Weight fractions, wing loading, and thrust-to-weight trends among MAVs and UAVs. Structural and battery weight estimation. Aerodynamics of bodies at very low Reynolds numbers. Thrust-to-weight ratio and wing loading selection from mission requirements. Wing design. Propeller design and motor selection. Layout and sketch of 3-view. Improved weight and drag estimation. Tail sizing for stability. Control surface design and choice of autopilot. Performance evaluation. Special considerations – launch, operation, and recovery.

AS 6080 Theory of interior and intermediate ballistics

Introduction to fundamentals: Thermodynamics, thermochemistry, combustion, Use of CEA software. Introductory concepts of ballistics: .Guns and projectiles: Types and classification, interior, intermediate, exterior and terminal ballistics, ballistic terminology. Analytical formulation of interior ballistic phenomena: Gunpowder combustion and projectile motion – Lagrangian approach – pressure travel curves, interior ballistic trajectories during burning – effect of parameters – types of propellant, chamber and barrel configurations, sensitivity and efficiency analysis. Extension of interior ballistic theory to high-velocity weapons. Design of ammunition: construction of propellant charges, cartridge case, structural analysis of the shell -full bore and sub-caliber-sabot – prediction of stresses and failure, design of buttress threads and barrel. Intermediate ballistics: primary, secondary blasts and other flow interfaces, projectile-flow interactions, analytical prediction of projectile aerodynamic characteristics. Gun dynamics: Recoil, flow through muzzle brakes, measurement of projectile travel near the start of motion, in-bore velocity and acceleration measurement.

AS 6090 Theory of exterior and terminal ballistics

Introductory concepts: Trajectories- vacuum, simple air (Flat fire)-Wind effects. Point mass trajectory, 6-DoF trajectory, modified point mass trajectory. Linearized aero-ballistics: pitching and yawing motions, Gyroscopic and dynamic stabilities, Yaw of repose, Roll resonance, Mass asymmetries, Lateral throw-off: Static and dynamic imbalances, Swerve motion: Aerodynamic jump, drift of spinning bodies and slender bodies Non-linear aero-ballistics. Terminal ballistics: Introduction to penetration theories, penetration on concrete, soils, ceramics and composites, pentation from various projectiles, Chemical and kinetic energy projectiles. Armors: Rolled Homogeneous armors and explosive reactive armor.

AS 6095 Design of Ammunition

Overview of ammunition types and applications, History and evolution of ammunition design, ammunition Types: Fixed ammunition, separable ammunition, separate-loaded ammunition, Internal, external, and terminal ballistics, kinetic energy and penetration, fragmentation, and lethality, Propellants and Explosives, Types of firearms and their components, Explosives and their properties, Guns and Barrels, Mechanics of gun operation, Consistency, and accuracy. Design of propellant: Types of propellants and their characteristics, Chemical reactions and combustion processes, Design considerations and safety principles, case designs Projectile design: full caliber and sub-caliber projectiles: aerodynamic, stability, structural and material considerations in interior, intermediate exterior, and terminal phases. Barrel and muzzle brake design: Rifled and smooth bore, Gun & barrel dynamics: estimation of forces and moments, material considerations, autofrettage process, barrel coating. Fusing and Timing: Types of fuses and their functions, Design of electronic and mechanical timing devices, Safety, and arming mechanisms Testing and Evaluation: Laboratory testing procedures and protocols, Field testing and evaluation of ammunition, Quality control and manufacturing considerations, Ethical and legal considerations, Future ammunition.

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