Indian Institute of Space Science and Technology

Thiruvananthapuram

M.Tech. Structures and Design
Curriculum and Syllabus

(Effective from 2019 Admission)

Department of Aerospace Engineering

Program Educational Objectives (PEO)

1. To provide fundamental theoretical knowledge in the specialised areas related to Structural Engineering.

2. To develop skills in understanding and applying advanced Computational Structures technology applicable to static and dynamic analyses of structures.

3. To impart skills in the Design, Analysis and Testing practices of Mechanical / Aerospace Structures.

4. To promote academic learning and research activities in the modern structural engineering and materials.

Program Outcomes (PO)

1. An ability to independently carry out research /investigation and development work to solve practical problems.

2. An ability to write and present a substantial technical report/document.

3. Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program.

4. Capability to Innovate, design and analyze components related to structural engineering, and aerospace engineering.

5. Ability to perform multidisciplinary analysis involving Structural engineering for aerospace applications.

6. Ability to perform experimental, numerical simulations and theoretical study for modeling of aerospace structural systems.

7. Guidance to upkeep professional ethics in all scientific and engineering practices.

SEMESTER I

CODE	TITLE	L	T	P	C
AE601	Mathematical Methods in Aerospace Engg.	3	0	0	3
AE603	Elements of Aerospace Engineering	3	0	0	3
AE631	Advanced Solid Mechanics	3	0	0	3
AE632	Finite Element Method	3	0	0	3
AE633	Structural Dynamics	3	0	0	3
E01	*Elective I*	3	0	0	3
	Total	18	0	0	18

SEMESTER II

CODE	TITLE	L	T	P	C
AE634	Mechanics of Composite Materials	3	0	0	3
E02	*Elective II*	3	0	0	3
E03	*Elective III*	3	0	0	3
E04	*Elective IV*	3	0	0	3
E05	*Elective V*	3	0	0	3
E06	*Elective VI*	3	0	0	3
AE803	Aerospace Structures Lab	0	0	3	1
	Total	18	0	3	19

SEMESTER III

CODE	TITLE	L	T	P	C
AE851	Seminar	0	0	0	1
AE852	Project Work – Phase I	0	0	0	15
	Total	0	0	0	16

SEMESTER IV

CODE	TITLE	L	T	P	C
AE852	Project Work – Phase II	0	0	0	17

LIST OF ELECTIVES

CODE	TITLE
AE701	Linear Algebra and Perturbation Methods
AE703	Probability and Statistics for Engineers
AE704	Operations Research
AE750	Artificial Intelligence and Robots
AE751	Aeroelasticity
AE752	Continuum Mechanics
AE753	Introduction to Robotics
AE754	Multi-Rigid Body Dynamics
AE755	Energy Methods in Structural Mechanics
AE756	Advanced Finite Element Method
AE757	Molecular Dynamics and Materials Failure
AE758	Fracture Mechanics and Fatigue
AE759	Stochastic Mechanics and Structural Reliability
AE760	Elastic Wave Propagation in Solids
AE761	Aerospace Materials and Processes
AE762	Smart Materials and Structures
AE763	Structural Acoustics and Noise Control
AE764	Mechanics of Aerospace Structures
AE765	Design and Analysis of Aerospace Structures
AE766	Robot Mechanisms and Technologies
AE767	Rotordynamics
AE768	Experimental Modal Analysis
AE769	Random Vibrations and Applications

SEMESTER–WISE CREDITS

Semester	I	II	III	IV	Total
Credits	18	19	16	17	70

SEMESTER I

AE601 MATHEMATICAL METHODS IN AEROSPACE ENGINEERING (3 – 0 – 0) 3 Credits

Review of Ordinary Differential Equations: analytical methods, stability – Fourier series, orthogonal functions, Fourier integrals, Fourier transform – Partial Differential Equations: first-order PDEs, method of characteristics, linear advection equation, Burgers' equation, shock formation, Rankine-Hogoniot jump condition; classification, canonical forms; Laplace equation, min-max principle, cylindrical coordinates; heat equation, method of separation of variables, similarity transformation method; wave equation, d'Alembert solution – Calculus of Variations: standard variational problems, Euler-Lagrange equation and its applications, isoperimetric problems, Rayleigh-Ritz method, Hamilton's principle of least action.

References:

1. Brown, J. W. and Churchill, R. V., *Fourier Series and Boundary Value Problems*, 8th ed., McGraw-Hill, (2012).
2. Bleecker, D. D. and Csordas, G., *Basic Partial Differential Equations*, Van Nostrand Reinhold (1992).
3. Myint-U, T. and Debnath, L., *Linear Partial Differential Equations for Scientists and Engineers*, 4th ed., Birkhauser (2006).
4. Strauss, W. A., *Partial Differential Equations: An Introduction*, 2nd ed., John Wiley (2008).
5. Kot, M., *A First Course in the Calculus of Variations*, American Math Society (2014).
6. Gelfand, I. M. and Fomin, S. V., *Calculus of Variations*, Prentice Hall (1963).
7. Arfken, G. B., Weber, H. J., and Harris, F. E., *Mathematical Methods for Physicists*, 7th ed., Academic Press (2012).
8. Greenberg, M. D., *Advanced Engineering Mathematics*, 2nd ed., Pearson (1998).

Course Outcomes (COs):

CO1: Develop a general understanding of linear algebra in terms of vector spaces and its application to differential equations and Fourier analysis.

CO2: Ability to use Fourier analysis techniques for solving PDE and for signal analysis.

CO3: Formulate physical problems in terms of ODE/PDE and obtain analytical solutions.

CO4: Use commercial/open-source math packages for solving ODE and performing signal analysis.

AE603 ELEMENTS OF AEROSPACE ENGINEERING (3 – 0 – 0) 3 Credits

History of aviation – types of flying machines – anatomy of an aircraft; fundamental aerodynamic variables – aerodynamic forces – lift generation – airfoils and wings – aerodynamic moments – concept of static stability – control surfaces; mechanism of thrust production – propellers – jet engines and their operation – elements of rocket propulsion; loads acting on an aircraft – load factor for simple maneuvers – Vn diagrams; aerospace materials; introduction to aerospace structures; basic orbital mechanics – satellite orbits; launch vehicles and reentry bodies.

References:

1. Anderson, J. D., *Introduction to Flight*, 7th ed., McGraw-Hill (2011).

2. Anderson, D. F. and Eberhardt, S., *Understanding Flight*, 2nd ed., McGraw-Hill (2009).
3. Szebehely, V. G. and Mark, H., *Adventures in Celestial Mechanics*, 2nd ed., Wiley (1998).
4. Turner, M. J. L., *Rocket and Spacecraft Propulsion: Principles, Practice and New Developments*, 3rd ed., Springer (2009).

Course Outcomes (COs):
CO1: Develop a basic understanding about the classification of aircraft and its anatomy.
CO2: Equip with fundamental aerodynamic concepts related to aircraft.
CO3: Develop a basic knowledge about aircraft performance, aerospace materials and structures.
CO4: Exposure to various air breathing engines and its working principle for thrust generation in aircraft.
CO5: Equip with the basics of rocket propulsion and orbital mechanics.

AE631 **ADVANCED SOLID MECHANICS** (3 – 0 – 0) 3 Credits

Review of basic equations of elasticity – state of stress at a point – analysis of strain, constitutive relations – generalized Hook's law – formulation of boundary value problems – solution of 2D problems – energy methods in elasticity – bending, shear and torsion – thin walled beams – applications.

Textbook:

- Sadd, M. H., *Elasticity: Theory, Applications, and Numerics*, 3rd ed., Academic Press (2014).

References:

1. Srinath, L. S., *Advanced Mechanics of Solids*, 3rd ed., Tata McGraw-Hill (2010).
2. Mase, G. T., Smelser, R. E., and Mase, G. E., *Continuum Mechanics for Engineers*, 3rd ed., CRC Press (2009).
3. Timoshenko, S. P. and Goodier, J. N., *Theory of Elasticity*, 3rd ed., McGraw-Hill (1970).

Course Outcomes (COs):
CO1: Develop advanced concepts of deformation, stress and strain with ability to represent and transform these quantities in different coordinate systems.
CO2: Develop constitutive relationships between stress and strain for linearly elastic solid.
CO3: Formulate boundary value problems in elasticity and grasp the various solution methodologies.
CO4: Apply techniques to determine shear centre and stress in thin-walled beams subjected to bending and torsion.

AE632 **FINITE ELEMENT METHOD** (3 – 0 – 0) 3 Credits

Introduction – approximate solutions to governing differential equations (GDE) – finite element formulations starting from GDE – finite element formulations based on stationarity of a functional – one-dimensional finite element analysis; shape functions, types of elements and applications – two- and three-dimensional finite elements – numerical integration – applications to structural mechanics and fluid flow.

References:

1. Reddy, J. N., *Introduction to the Finite Element Method*, 3rd ed., McGraw-Hill (2006).
2. Seshu, P., *Textbook of Finite Element Analysis*, Prentice Hall of India (2009).
3. Chandrupatla, T. R. and Belegundu, A. D., *Introduction to Finite Elements in Engineering*, 2nd ed., Prentice Hall of India (2000).
4. Segerlind, L. J., *Applied Finite Element Analysis*, 2nd ed., John Wiley (1984). (1992).

Course Outcomes (COs):

CO1: Students should have an understanding of the theory and procedures of Finite Element (FE).

CO2: Develop 1D & 2D elements for structural mechanics problems. Solve problems related to element formulation both from GDE and Potential, and those related to numerical integration.

CO3: Should be able to develop a code for simple 1D & 2D FE problems so that proper element selection, convergence, input and output are understood by the students. Should be able to implement the various procedures of FE to create the code.

CO4: Use a commercial FE program to solve a 2D sufficiently complex problem wherein modeling, element selection, and post-processing issues are understood. Should be able to differentiate and compare between some of the elements available for the solution of a problem. Analyse the issues that could occur due to improper selection of elements.

AE633 | STRUCTURAL DYNAMICS | (3 – 0 – 0) 3 Credits

Elements of analytical dynamics – discrete systems with multiple degrees of freedom – elastic and inertia coupling – natural frequencies and mode – free vibration response – uncoupling of equations of motion – modal analysis – forced vibration response – vibration isolation – vibration of continuous systems – differential equations and boundary conditions – longitudinal, flexural and torsional vibrations of one-dimensional structures – vibration analysis of simplified aircraft and launch vehicle structures – structural damping – free and forced response of continuous systems – introduction to concepts of nonlinear and random vibrations – elements of vibration testing and experimentation.

References:

1. Meirovitch, L., *Elements of Vibration Analysis*, 2nd ed., McGraw-Hill (1986).
2. Paz, M., *Structural Dynamics: Theory and Computation*, 2nd ed., CBS Publishers & Distributors (2004).
3. Weaver Jr., W., Timoshenko, S. P., and Young, D. H., *Vibration Problems in Engineering*, 5th ed., John Wiley (1990).
4. Meirovitch, L., *Computational Methods in Structural Dynamics*, Sijthoff & Noordhoff (1980).
5. Cough, R. W. and Penzien, J., *Dynamics of Structure*, 2nd ed., McGraw-Hill (1993).

Course Outcomes (COs):

CO1: Apply the knowledge of mathematics, science, and engineering by developing the equations of motion for vibratory systems and solving for the free and forced response .

CO2: Create simple computational models for engineering structures using the knowledge of structural dynamics.

CO3: Interpret the dynamic analysis results for design, analysis and research purposes.

E01 | ELECTIVE I | (3 – 0 – 0) 3 Credits

- Refer list of electives

SEMESTER II

AE634 MECHANICS OF COMPOSITE MATERIALS (3 – 0 – 0) 3 Credits

Introduction, definition, classification, behaviors of unidirectional composites – prediction of strength, stiffness – factors influencing strength and stiffness – failure modes – analysis of lamina; constitutive classical laminate theory – thermal stresses – theories of failure – design consideration – mechanical properties of composite materials – analysis of composite laminated beams – thin walled composite beams – bending of composite plates.

References:

1. Jones, R. M., *Mechanics of Composite Materials*, 2nd ed., CRC Press (1998).
2. Kollar, L. P. and Springer, G. S., *Mechanics of Composite Structures*, Cambridge Univ. Press (2003).
3. Altenbach, H., Altenbach, J., and Kissing, W., *Mechanics of Composite Structural Elements*, Springer (2000).

Course Outcomes (COs):
CO1: Introduce to advanced composite materials and their applications.
CO2: Develop micro-mechanical and macro-mechanical relationships for lamina and laminated materials.
CO3: Failure analysis of the composites.
CO4: To material, structural, and strength optimization to design laminated composite materials.

E02 ELECTIVE II (3 – 0 – 0) 3 Credits

- Refer list of electives

E03 ELECTIVE III (3 – 0 – 0) 3 Credits

- Refer list of electives

E04 ELECTIVE IV (3 – 0 – 0) 3 Credits

- Refer list of electives

E05 ELECTIVE V (3 – 0 – 0) 3 Credits

- Refer list of electives

E06 **ELECTIVE VI** (3 – 0 – 0) 3 Credits

- Refer list of electives

AE803 **AEROSPACE STRUCTURES LAB** (0 – 0 – 3) 1 Credit

1. Strain measurements
2. Structural vibration
3. Wave propagation
4. Fabrication and testing of laminated composites
5. Static and stability behaviour of thin-walled structures
6. Non-destructive testing
7. Structural modelling and analysis in CAE environment

Course Outcomes (COs):

CO1: To verify, understand and apply the structural engineering concepts they learned by conducting simple experiments using benchmark experimental setups.

CO2: To develop simple experimental set ups using available resources by their own and conduct experiments to understand the mechanics involved in the problems that they come across in different fields of aerospace structural mechanics.

CO3: To develop the capability of using basic concepts for design of Aerospace structural components.

SEMESTER III

AE851 **SEMINAR** (0 – 0 – 0) 1 Credit

AE852 **PROJECT WORK — PHASE I** (0 – 0 – 0) 15 Credits

SEMESTER IV

AE852 **PROJECT WORK — PHASE II** (0 – 0 – 0) 17 Credits

Electives

AE701 LINEAR ALGEBRA AND PERTURBATION METHODS (3 – 0 – 0) 3 Credits

Vector Space, norm, and angle – linear independence and orthonormal sets – row reduction and echelon forms, matrix operations, including inverses – effect of round-off error, operation counts – block/banded matrices arising from discretization of differential equations – linear dependence and independence – subspaces and bases and dimensions – orthogonal bases and orthogonal projections – Gram-Schmidt process – linear models and least-squares problems – eigenvalues and eigenvectors – diagonalization of a matrix – symmetric matrices – positive definite matrices – similar matrices – linear transformations and change of basis – singular value decomposition.

Introduction to perturbation techniques – asymptotic approximations, algebraic equations – regular and singular perturbation methods – application to differential equations – methods of strained co-ordinates for periodic solutions – Poincaré–Lindstedt method.

References:

1. Strang, G., *Introduction to Linear Algebra*, 4^{th} ed., Cambridge Univ. Press (2011).
2. Strang, G., *Linear Algebra and its Applications*, 4^{th} ed., Cengage Learning (2007).
3. Lang S., *Linear Algebra*, 2^{nd} ed., Springer (2004).
4. Golub, G. H. and Van Loan, C. F., *Matrix Computations*, 4^{th} ed., Hindustan Book Agency (2015).
5. Nayfe, A. H., *Introduction to Perturbation Techniques*, Wiley-VCH (1993).
6. Bender, C. M. and Orszag, S. A., *Advanced Mathematical Methods for Scientists and Engineers: Asymptotic Methods and Perturbation Theory*, Springer (1999).

AE703 PROBABILITY AND STATISTICS FOR ENGINEERS (3 – 0 – 0) 3 Credits

AE704 OPERATIONS RESEARCH (3 – 0 – 0) 3 Credits

Introduction – linear programming – revised simplex method – duality and sensitivity analysis – dual simplex method – goal programming – integer programming – network optimization models – dynamic programming – nonlinear programming – unconstrained and constrained optimization – nontraditional optimization algorithms.

References:

1. Ravindran, A., Phillips, D. T., and Solberg, J. J., *Operations Research: Principles and Practice*, 2^{nd} ed., John Wiley (2012).
2. Taha, H. A., *Operations Research: An Introduction*, 9^{th} ed., Prentice Hall of India (2010).
3. Winston, W. L., *Operations Research: Applications and Algorithms*, 4^{th} ed., Cengage Learning (2010).
4. Rao, S. S., *Engineering Optimization: Theory and Practices*, 4^{th} ed., John Wiley (2009).

5. Deb, K., *Optimization for Engineering Design: Algorithms and Examples*, 2^{nd} ed., Prentice Hall of India (2012).

Course Outcomes (COs):

CO1: Apply basic concepts of mathematics to formulate an optimization problem.

CO2: Analyze and solve general linear programming, integer programming and other operations research problems.

CO3: Analyze and solve various constrained and unconstrained non-linear programming problems in single variable as well as multivariable.

CO4: Implement computer codes for mathematical as well non-traditional methods, and analyze the results.

AE751 AEROELASTICITY (3 – 0 – 0) 3 Credits

Introduction to static and dynamic aeroelastic phenomena – divergence, control efficiency and control reversal – two dimensional analysis – divergence of unswept wings – effect of sweep on divergence and control reversal – two-dimensional (airfoil) flutter analysis with quasi-steady and unsteady aerodynamic loads – introduction to buffeting, stall flutter, galloping and vortex-induced oscillations problems.

References:

1. Hodges, D. H. and Pierce, G. A., *Introduction to Structural Dynamics and Aeroelasticity*, 2^{nd} ed., Cambridge Univ. Press (2011).
2. Fung, Y. C., *An Introduction to the Theory of Aeroelasticity*, Dover (1969).
3. Bisplinghoff, R. L., Ashley, H., and Halfman, R. L., *Aeroelasticity*, Dover (1996).

AE752 CONTINUUM MECHANICS (3 – 0 – 0) 3 Credits

Review of tensor algebra – tensor analysis – concept of continuum – kinematics of a deformable body – deformation and strain – motion and flow – analysis of stress-stress tensors – conservation laws, mass and momentum conservation – continuum thermodynamics – first and second laws applied to a continuum – Clausius-Duhem inequality – constitutive relations – applications.

References:

1. Gurtin, M. E., Fried, E., and Anand, L., *The Mechanics and Thermodynamics of Continua*, Cambridge Univ. Press (2009).
2. Jog, C. S., *The Foundations and Applications of Continuum Mechanics*, Narosa Publications (2002).
3. Mase, G. E., *Continuum Mechanics*, Schaum's Outline Series, McGraw-Hill (1969).
4. Spencer, A. J. M., *Continuum Mechanics*, Dover (2004).
5. Malvern, L. E., *Introduction to Mechanics of a Continuous Medium*, Prentice Hall (1969).
6. Chadwick, P., *Continuum Mechanics: Concise Theory and Problems*, Dover (1999).

AE753 INTRODUCTION TO ROBOTICS (3 – 0 – 0) 3 Credits

Overview of robotics – manipulators and field robots; robot mechanisms - serial chains, regional and orientational mechanisms, parallel chains, reachable and dexterous work space, mechanisms of wheeled and walking robots; spatial displacements, rotation matrices, Euler angles, homogenous transformation, D-H parameters, forward and inverse problems for serial and parallel manipulators; task planning – joint space and task space planning; sensors – joint displacement sensors, force sensors, range finders, vision sensors; actuators - electric motors - stepper, PMDC and brushless DC motors, pneumatic and hydraulic actuators; speed reducers; Servo control of manipulators - joint feedback control, effect of nonlinearities, inverse dynamic control, force feedback control; higher level control – path planning, configuration space, road map methods, graph search algorithms, potential field method.

References:

1. Siciliano, B., Sciavicco, L., Villani, L., and Oriolo, G., *Robotics: Modelling, Planning and Control*, Springer (2009).
2. Ghosal, A., *Robotics: Fundamental Concepts and Analysis*, Oxford Univ. Press (2006).
3. Choset, H., Lynch, K. M., Hutchinson, S., Kantor, G., Burgard, W., Kavraki, L. E., and Thrun, S., *Principles of Robot Motion: Theory, Algorithms, and Implementations*, MIT Press, Prentice Hall of India (2005).

AE754 MULTI-RIGID BODY DYNAMICS (3 – 0 – 0) 3 Credits

Review of planar motion of rigid bodies and Newton-Euler equations of motion; constraints – holonomic and non-holonomic constraints, Newton-Euler equations for planar inter connected rigid bodies; D'Alembert's principle, generalized coordinates; alternative formulations of analytical mechanics and applications to planar dynamics – Euler-Lagrange equations, Hamilton's equations and ignorable coordinates, Gibbs-Appel and Kane's equations; numerical solution of differential and differential algebraic equations; spatial motion of a rigid body – Euler angles, rotation matrices, quaternions, Newton-Euler equations for spatial motion; equations of motion for spatial mechanisms.

References:

1. Ginsberg, J., *Engineering Dynamics*, Cambridge Univ. Press (2008).
2. Ardema, M. D., *Analytical Dynamics: Theory and Applications*, Kluwer Academic/Plenum Publishers (2005).
3. Fabien, B. C., *Analytical System Dynamics: Modeling and Simulation*, Springer (2009).
4. Harrison, H. R. and Nettleton, T., *Advanced Engineering Dynamics*, Arnold (1997).
5. Moon, F. C., *Applied Dynamics*, Wiley (1998).
6. Kane, T. R. and Levinson, D. A., *Dynamics: Theory and Applications*, McGraw-Hill (1985).

Course Outcomes (COs):
CO1: Apply basic particle dynamics to 2-dimensional and 3-dimensional rigid bodies.
CO2: Analyse and derive equations of motion using different formulations for multi-body systems.
CO3: Use numerical methods to find solutions of equations.

AE755 ENERGY METHODS IN STRUCTURAL MECHANICS (3 – 0 – 0) 3 Credits

The variational principle and the derivation of the governing equations of static and dynamic systems – different energy methods: Rayleigh-Ritz, Galerkin etc. – applications: 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.

References:

1. Langhaar, H. L., *Energy Methods in Applied Mechanics*, 2nd ed., Krieger Publishing Co. (1989).
2. Reddy, J. N., *Energy and Variational Methods in Applied Mechanics*, 2nd ed., Wiley (2002).
3. Tauchert, T. R., *Energy Principles in Structural Mechanics*, McGraw-Hill (1974).

AE756 ADVANCED FINITE ELEMENT METHOD (3 – 0 – 0) 3 Credits

Finite element formulations for beam, plate, shell (Kirchhoff and Mindlin-Reissner), and solid elements – large deformation nonlinearity – nonlinear bending of beams and plates – stress and strain measures – total Lagrangian and updated Lagrangian formulations – material nonlinearity – ideal and strain hardening plasticity – elastoplastic analysis – boundary nonlinearity – general contact formulations – solution procedures for nonlinear analysis, Newton-Raphson iteration method.

References:

1. Reddy, J. N., *Introduction to Nonlinear Finite Element Analysis*, Oxford Univ. Press (2010).
2. Bathe, K. J., *Finite Element Procedures*, 2nd ed., Klaus-Jurgen Bathe (2014).

AE757 MOLECULAR DYNAMICS AND MATERIALS FAILURE (3 – 0 – 0) 3 Credits

Introduction – materials deformation and fracture phenomena – strength of materials: flaws, defects, and a perfect material, brittle vs. ductile material behavior, the need for atomistic simulations – applications basic atomistic modeling – classical molecular dynamics – interatomic potential-numerical implementation – visualisation – atomistic elasticity, the virial stress and strain – multiscale modeling and simulation methods – deformation and dynamical failure of brittle and ductile materials – applications.

References:

1. Buehler, M. J., *Atomistic Modeling of Materials Failure*, Springer (2008).
2. Doeblin, E. O., *Understanding Molecular Simulation: from Algorithms to Applications*, Academic Press (2001).
3. Rapaport, D. C., *The Art of Molecular Dynamics Simulation*, 2nd ed., Cambridge Univ. Press (2004).

AE758 FRACTURE MECHANICS AND FATIGUE (3 – 0 – 0) 3 Credits

Linear elastic fracture mechanics; energy release rate, stress intensity factor (SIF), relation between SIF and energy release rate, anelastic deformation at the crack tip – J-integral, CTOD, test methods for fracture toughness – crack growth and fracture mechanisms, mixed-mode fracture, fracture at nanoscale – numerical methods for analysing fracture, applications – fatigue and design against fatigue failure – prediction of fatigue life.

References:

1. Prashant Kumar, *Elements of Fracture Mechanics*, Tata McGraw-Hill (2009).
2. Anderson, T. L., *Fracture Mechanics: Fundamentals and Applications*, 3rd ed., CRC Press (2004).
3. Buehler, M. J., *Atomistic Modeling of Materials*, Springer (2008).

AE759 STOCHASTIC MECHANICS AND STRUCTURAL RELIABILITY (3 – 0 – 0) 3 Credits

Basics of probability theory: axioms, definitions, random variable – probability structure of random variable – joint distributions – functions of random variables – some common random variables – random processes/random fields.

Structural reliability – fundamental concepts – first order reliability methods – second order reliability methods – probabilistic sensitivity – system reliability – simulation techniques – high dimensional model representation techniques for reliability analysis.

Stochastic finite element analysis for structural mechanics problems – random field discretization – perturbation method – Neumann expansion method.

References:

1. Ang, A. H-S. and Tang, W. H., *Probability Concepts in Engineering Planning and Design: Volume I Basic Principles*, Wiley (1975).
2. Ang, A. H-S. and Tang, W. H., *Probability Concepts in Engineering Planning and Design: Volume II Risk and Reliability*, Wiley (1984).
3. Halder A., Mahadevan, S., *Probability, Reliability and Statistical Methods in Engineering Design*, Wiley (2000).
4. Ghanem, R. G., Spanos, P. D., *Stochastic Finite Elements: A Spectral Approach*, Springer (1991).
5. Melchers, R. E., *Structural Reliability Analysis and Prediction*, Wiley (1999).

AE760 ELASTIC WAVE PROPAGATION IN SOLIDS (3 – 0 – 0) 3 Credits

Review of vibration of structural elements – one-dimensional motion in elastic media – discrete Fourier transform – spectral finite element method – standing waves – flexural waves in beams and plates – torsional waves in shafts – guided waves – structural health monitoring using wave propagation.

References:

1. Rose, J. L., *Ultrasonic Waves in Solid Media*, Cambridge Univ. Press (1999).
2. Rose, J. L., *Ultrasonic Guided Waves in Solid Media*, Cambridge Univ. Press (2014).
3. Achenbach, J. D., *Wave Propagation in Elastic Solids*, Elsevier (1973).
4. Graff, K. F., *Wave Motion in Elastic Solids*, Dover (1991).

AE761 AEROSPACE MATERIALS AND PROCESSES (3 – 0 – 0) 3 Credits

Properties of materials: strength, hardness, fatigue, and creep – Ferrous alloys: stainless steels, maraging steel, aging treatments – Aluminum alloys: alloy designation and tempers, Al-Cu alloys, principles of age hardening, hardening mechanisms, Al-Li alloys, Al-Mg alloys, nanocrystalline aluminum alloys – Titanium alloys: α-β alloys, superplasticity, structural titanium alloys, intermetallics

– Magnesium alloys: Mg-Al and Mg-Al-Zn alloys – Superalloys: processing and properties of superalloys, single-crystal superalloys, environmental degradation and protective coatings – Composites: metal matrix composites, polymer based composites, ceramic based composites, carbon carbon composites.

References:

1. Polmear, I. J., *Light Alloys: From Traditional Alloys to Nanocrystals*, 4^{th} ed., Elsevier (2005).
2. Reed, R. C., *The Superalloys: Fundamentals and Applications*, Cambridge Univ. Press (2006).
3. Gupta, B., *The Aerospace Materials*, S. Chand Publishing (2002).
4. Cantor, B., Assender, H., and Grant, P. (Eds.), *Aerospace Materials*, CRC Press (2001).
5. *ASM Speciality Handbook: Heat Resistant Materials*, ASM International (1997).
6. Campbell, F. C., *Manufacturing Technology for Aerospace Structural Materials*, Elsevier (2006).
7. Kainer, K. U. (Ed.), *Metal Matrix Composites*, Wiley-VCH (2006).

AE762 SMART MATERIALS AND STRUCTURES (3 – 0 – 0) 3 Credits

Overview of smart materials – piezoelectric ceramics – piezo-polymers – magnetostrictive materials – electroactive polymers – shape memory alloys – electro and magneto rheological fluids.

Mechanics of Piezoelectric Materials and Systems: constitutive modelling – actuator and sensor – piezoelectric beams and plates. Shape Memory Alloys: constitutive modelling – actuation models. Electroactive polymer materials applications.

Textbook:

- Leo, D. J., *Engineering Analysis of Smart Material Systems*, Wiley (2007).

References:

1. Culshaw, B., *Smart Structures and Materials*, Artech House (1996).
2. Gaudenzi, P., *Smart Structures: Physical Behaviour, Mathematical Modelling and Applications*, Wiley (2009).

Course Outcomes (COs):

CO1: Apply the knowledge of mathematics, science, and engineering by developing constitutive equations of piezoelectric materials and systems.

CO2: Use of Phenomenological models of Shape memory alloys for designing actuator systems.

CO3: Interpret the analysis results, use it for design of actuator and sensor systems for smart structures.

AE763 STRUCTURAL ACOUSTICS AND NOISE CONTROL (3 – 0 – 0) 3 Credits

Basic acoustic principles – acoustic terminology and definitions – plane and spherical wave propagation – theories of monopole, dipole and quadrapole sound sources – sound transmission and absorption – sound transmission through ducts – structure borne sound – sound radiation and structural response – introduction to noise control.

References:

1. Munjal, M. L., *Noise and Vibration Control*, World Scientific Press (2013).

2. Williams, E. G., *Fourier Acoustics: Sound Radiation and Nearfield Acoustic Holography*, Academic Press (1999).
3. Kinsler, L. E., Frey, A. R., Coppens, A. B., and Sanders, J. V., *Fundamentals of Acoustics*, 4th ed., Wiley (2000).

Course Outcomes (COs):
CO1: Understand fundamentals of acoustic wave propagation.
CO2: Understand different acoustic sources and it's properties.
CO3: Understand and design Mufflers and Horns.
CO4: To know basic noise control measures.

AE764 **MECHANICS OF AEROSPACE STRUCTURES** (3 – 0 – 0) 3 Credits

Structural components of aircraft – loads and material selection – introduction to Kirchhoff theory of thin plates – bending and buckling of thin plates – unsymmetric bending of beams – bending of open and closed thin walled beams – shear and torsion of thin walled beams – combined open and closed section of beams – structural idealization.

References:

1. Polmear, I. J., *Light Alloys: From Traditional Alloys to Nanocrystals*, 4th ed., Elsevier (2005).
2. Reed, R. C., *The Superalloys: Fundamentals and Applications*, Cambridge Univ. Press (2006).
3. Gupta, B., *The Aerospace Materials*, S. Chand Publishing (2002).
4. Cantor, B., Assender, H., and Grant, P. (Eds.), *Aerospace Materials*, CRC Press (2001).
5. *ASM Speciality Handbook: Heat Resistant Materials*, ASM International (1997).
6. Campbell, F. C., *Manufacturing Technology for Aerospace Structural Materials*, Elsevier (2006).
7. Kainer, K. U. (Ed.), *Metal Matrix Composites*, Wiley (2006).

AE765 **DESIGN AND ANALYSIS OF AEROSPACE STRUCTURES** (3 – 0 – 0) 3 Credits

Design considerations – codes and standards – aerospace materials and their properties – selection of materials – failure theories – design criteria – strength, stiffness, fatigue, damage tolerance – fail safe and safe life designs – design aspects typical aerospace structural constructions: monocoque, stiffened plate, isogrid, sandwich and laminated composites – weight control – design of pressurized systems – configuration, design calculations and checks applied to typical aerospace structures – structural connections and joints – fasteners – design project.

References:

1. Shigley, J. E., Mischke, C., and Budynas, R., *Mechanical Engineering Design*, 7th ed., McGraw Hill (2003).
2. Bruhn, E. F., *Analysis and Design of Flight Vehicle Structures*, 2nd ed., Jacobs Publishing Inc. (1973).
3. Niu, M. C.Y., *Airframe Structural Design*, 2nd ed., Hongkong Conmilit Press Ltd. (2002).
4. Harvey, J. F., *Theory and Design of Modern Pressure Vessels*, 2nd ed., Van Nostrand (1974).

AE766 ROBOT MECHANISMS AND TECHNOLOGY (3 – 0 – 0) 3 Credits

Mechanisms of robots: Regional and orientational mechanisms of serial chain manipulators, gripper mechanisms, parallel chain manipulator mechanisms, leg mechanisms of walking robots, suspension and drive mechanisms of wheeled rovers, bio-robots, UAV's and Underwater robots. Representation of spatial mechanisms, and rigid body transformations Actuators, drives, and sensors in robotics.

References:

1. Craig, J. J., *Introduction to Robotics: Mechanics and Control*, 4^{rd} ed., (2017).
2. Siciliano, B. and Khatib, O. (Editors), *Springer Handbook of Robotics*, Springer (2008).
3. Nourbakhsh, I. R. and Siegwart, R., *Introduction to Autonomous Mobile Robots*, 2^{nd} ed., (2011).
4. Sclater, N., *Mechanisms and Mechanical Devices Sourcebook*, 5^{rd} ed., McGraw Hill (2011).
5. Vepa, R., *Biomimetic Robotics: Mechanisms and Control*, 5^{rd} ed., Cambridge Univ. Press (2009).
6. Sandin, P. E., , *Robot Mechanisms and Mechanical Devices Illustrated*, McGraw Hill (2003).

Course Outcomes (COs):

CO1: Understand the basic mechanisms in various robots.
CO2: Representation of robots using basic convention techniques.
CO3: Choosing of suitable actuator, drive, and sensor for a specific robot.

AE767 ROTORDYNAMICS (3 – 0 – 0) 3 Credits

AE768 EXPERIMENTAL MODAL ANALYSIS (3 – 0 – 0) 3 Credits

AE769 RANDOM VIBRATIONS AND APPLICATIONS (3 – 0 – 0) 3 Credits