Indian Institute of Space Science and Technology

Thiruvananthapuram

B.Tech. Aerospace Engineering

Curriculum & Syllabus

(For 2014 Admission)

Department of Aerospace Engineering

SEMESTER I

CODE	TITLE	L	T	P	C
MA111	Calculus	3	1	-	4
PH111	Physics I	3	1	-	4
CH111	Chemistry	2	1	-	3
AE111	Introduction to Aerospace Engineering	3	-	-	3
AV111	Basic Electrical Engineering	3	-	-	3
HS111	Communication Skills	2	-	3	3
PH131	Physics Lab	-	-	3	1
AE131	Basic Engineering Lab	-	-	3	1
	Total	16	3	9	22

SEMESTER II

CODE	TITLE	L	T	P	C
MA121	Vector Calculus and Differential Equations	2	1	-	3
MA122	Computer Programming and Applications	2	-	3	3
PH121	Physics II	3	1	-	4
CH121	Materials Science and Metallurgy	3	-	-	3
AV121	Basic Electronics Engineering	3	-	-	3
AE141	Engineering Graphics	1	-	3	2
CH141	Chemistry Lab	-	-	3	1
AV141	Basic Electrical and Electronics Engineering Lab	-	-	3	1
	Total	14	2	12	20

SEMESTER III

CODE	TITLE	L	T	P	C
MA211	Linear Algebra, Numerical Analysis, and Transforms	3	-	-	3
AE211	Engineering Thermodynamics	3	-	-	3
AE212	Mechanics of Solids	3	-	-	3
AE213	Fluid Mechanics	3	-	-	3
AE214	Manufacturing Technology	3	-	-	3
HS211	Introduction to Economics	2	-	-	2
AE231	Machine Drawing	1	-	3	2
AE232	Strength of Materials Lab	-	-	3	1
	Total	18	0	6	20

SEMESTER IV

CODE	TITLE	L	T	P	C
MA221	PDE, Calculus of Variations, and Complex Analysis	3	0	0	3
AE221	Gas Dynamics	3	0	0	3
AE222	Heat Transfer	3	0	0	3
AE223	Kinematics and Dynamics of Mechanisms	3	1	0	4
AE224	Metrology and Computer Aided Inspection	3	0	0	3
HS221	Introduction to Social Science and Ethics	2	0	0	2
AE241	Thermal and Fluid Lab	0	0	6	2
	Total	17	1	6	20

SEMESTER V

CODE	TITLE	L	T	P	C
MA311	Probability and Statistics	3	0	0	3
AE311	Aerodynamics	3	0	0	3
AE312	Aerospace Structures I	3	1	0	4
AE313	Manufacturing Technology II	3	0	0	3
AV315	Instrumentation and Control Systems	3	0	0	3
CH311	Environmental Science and Engineering	2	0	0	2
AE331	Aerodynamics Lab	0	0	3	1
AE332	Metrology Lab	0	0	3	1
AV335	Instrumentation and Control Systems Lab	0	0	3	1
	Total	17	1	9	21

SEMESTER VI

CODE	TITLE	L	T	P	C
AE321	Atmospheric Flight Mechanics	3	1	0	4
AE322	Spaceflight Mechanics	3	0	0	3
AE323	Air-Breathing Propulsion	3	0	0	3
AE324	Aerospace Structures II	3	1	0	4
E01	*Elective I*	3	0	0	3
HS321	Principles of Management Systems	3	0	0	3
AE341	Aerospace Structures Lab	0	0	3	1
AE342	Manufacturing Processes Lab	0	0	3	1
AE343	Modeling and Analysis Lab	0	0	3	1
	Total	18	2	9	23

SEMESTER VII

CODE	TITLE	L	T	P	C
AE411	Rocket Propulsion	3	0	0	3
AE412	Aerospace Vehicle Design	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	*Institute Elective*	3	0	0	3
AE431	Flight Mechanics and Propulsion Lab	0	0	3	1
AE451	Summer Internship and Training	0	0	0	3
AE452	Comprehensive Viva-Voce I	0	0	0	2
	Total	18	0	3	24

SEMESTER VIII

CODE	TITLE	L	T	P	C
AE453	Comprehensive Viva-Voce II	0	0	0	3
AE454	Project Work	0	0	0	12
	Total	0	0	0	15

SEMESTER–WISE CREDITS

Semester	I	II	III	IV	V	VI	VII	VIII	Total
Credits	22	20	20	20	21	23	24	15	165

LIST OF ELECTIVES

CODE	TITLE
AE461	Advanced Aerodynamics
AE462	Advanced Aerospace Structures
AE463	Advanced Fluid Mechanics
AE464	Advanced Heat Transfer
AE465	Advanced Propulsion Systems
AE466	Structural Dynamics and Aeroelasticity
AE467	Analysis and Design of Composite Structures
AE468	Computational Fluid Dynamics
AE469	Computer Integrated Manufacturing
AE470	Design of Aerospace Structures
AE471	Convection Heat Transfer
AE472	Experimental Aerodynamics
AE473	Finite Element Method
AE474	Fracture Mechanics
AE475	Engineering Vibration
AE476	Industrial Engineering
AE477	Fundamentals of Combustion
AE478	Supply Chain Management
AE479	Introduction to Optimization
AE480	Nontraditional Machining
AE481	Operations Research
AE482	Structural Acoustics and Noise Control
AE483	Introduction to Robotics
AE484	Space Mission Design and Optimization
AE485	Quality Engineering and Management
AE486	Refrigeration and Cryogenics

AE487	Turbomachines
AE488	Advanced Manufacturing and Automation
AE489	Aerospace Materials and Processes
AE490	Heat Transfer in Space Applications
AE491	Structural Dynamics
AE492	Hypersonic Aerothermodynamics
AE493	Two-Phase Flow and Heat Transfer
AE494	Turbulence in Fluid Flows
AE495	High Temperature Gas Dynamics
AE496	Multidisciplinary Design Optimisation
AE497	Multi-Rigid Body Dynamics
AE498	Computational Methods for Compressible Flow
AE499	Elastic Wave Propagation in Solids

Note: Blue colour font indicates Institute Electives

SEMESTER I

MA111 | CALCULUS | (3 – 1 – 0) 4 credits

Sequence and Series of Real Numbers: sequence – convergence – limit of sequence – non-decreasing sequence theorem – sandwich theorem (applications) – L'Hopital's rule – infinite series – convergence – geometric series – tests of convergence (n^{th} term test, integral test, comparison test, ratio and root test) – alternating series and conditional convergence – power series.

Differential Calculus: functions of one variable – limits, continuity and derivatives – Taylors theorem – applications of derivatives – curvature and asymptotes – functions of two variables – limits and continuity – partial derivatives – differentiability, linearization and differentials – extremum of functions – Lagrange multipliers.

Integral Calculus: lower and upper integral – Riemann integral and its properties – the fundamental theorem of integral calculus – mean value theorems – differentiation under integral sign – numerical Integration- double and triple integrals – change of variable in double integrals – polar and spherical transforms – Jacobian of transformations.

Textbooks:

1. Stewart, J., *Calculus: Early Transcendentals*, 7^{th} ed., Cengage Learning (2010).
2. Jain, R. K. and Iyengar, S. R. K., *Advanced Engineering Mathematics*, 4^{th} ed., Alpha Science Intl. Ltd. (2013).

References:

1. Greenberg, M. D., *Advanced Engineering Mathematics*, Pearson Education (2007).
2. James, G., *Advanced Modern Engineering Mathematics*, 3^{rd} ed., Pearson Education (2005).
3. Kreyszig, E., *Advanced Engineering Mathematics*, 10^{th} ed., John Wiley (2011).
4. Thomas, G. B. and Finney, R. L., *Calculus and Analytic Geometry*, 9^{th} ed., Pearson Education (2003).

PH111 | PHYSICS I | (3 – 1 – 0) 4 credits

Vectors, Statics, and Kinematics: introduction to vectors (linear independence, completeness, basis, dimensionality), inner products, orthogonality – principles of statics, system of forces in plane and space, conditions of equilibrium – displacement, derivatives of a vector, velocity, acceleration – kinematic equations – motion in plane polar coordinates.

Newtonian Mechanics: momentum, force, Newton's laws, applications – conservation of momentum, impulse, center of mass.

Work and Energy: integration of the equation of motion – work energy theorem, applications – gradient operator – potential energy and force - interpretation – energy diagrams – law of conservation of energy – power – particle collisions.

Rotations: angular momentum – torque on a single particle – moment of inertia – angular momentum of a system of particles – angular momentum of a rotating rigid body.

Central Force Motion: central force motion of two bodies – relative coordinates – reduction to one dimensional problem – spherical symmetry and conservation of angular momentum, consequences – planetary motion and Kepler's laws.

Harmonic Oscillator: 1-D harmonic oscillator – damped and forced harmonic oscillators.

Modern Physics: relativity – introduction to quantum physics – atom model – hydrogen atom.

Textbook:

- Kleppner, D. and Kolenkow, R. J., *An Introduction to Mechanics*, 2nd ed., Cambridge Univ. Press (2013).

References:

1. Serway, R. A. and Jewett, J. W., *Principles of Physics: A Calculus Based Text*, 5th ed., Thomson Brooks/Cole (2012).
2. Halliday, D., Resnick, R., and Walker, J., *Fundamentals of Physics*, 9th ed., John Wile (2010).
3. Young, H. D., Freedman, R. A., Sundin, T. R., and Ford, A. L., *Sears and Zemansky's University Physics*, 13th ed., Pearson Education (2011).

CH111 CHEMISTRY (2 – 1 – 0) 3 credits

Chemical Kinetics: basic concepts of chemical kinetics – complex reactions – effect of temperature on reaction rates – catalysis.

Electrochemical Systems: introduction to electrochemistry – different types of electrodes – half cell potential – electromotive force – Gibbs free energy and cell potential – Nernst equation – electrochemical series – classification of electrochemical cells.

Corrosion Science: definition – causes and consequences – significance and methods of corrosion control – mechanisms and theories of corrosion.

Spectroscopy: fundamentals of spectroscopy – electronic spectroscopy – vibrational spectroscopy – other spectroscopic techniques.

Propellants: classification of propellants – performance of propellants and thermochemistry – liquid propellants – oxidizers and fuels – solid propellants – composite solid propellants – propellant processing.

Textbook:

- Atkins, P. and de Paula, J., *Atkins' Physical Chemistry*, 9th ed., Oxford Univ. Press (2009).

References:

1. Laidler, K. J., *Chemical Kinetics*, 3rd ed., Pearson Education (2005).
2. Kemp, W., *Organic Spectroscopy*, Palgrave Foundations (1991).
3. Revie, R. W. and Uhlig, H. H., *Corrosion and Corrosion Control – An Introduction to Corrosion Science and Engineering*, 4th ed., Wiley (2008).
4. Bockris, J. O'M. and Reddy, A. K. N., *Modern Electrochemistry 1: Ionics*, 2nd ed., Springer (1998).

AE111 INTRODUCTION TO AEROSPACE ENGINEERING (3 – 0 – 0) 3 credits

History of aviation – standard atmosphere – aerodynamic forces – lift generation – airfoils and wings – drag polar – concept of static stability – anatomy of an aircraft – mechanism of thrust production – propellers – jet engines and their operation – helicopters – aircraft performance – simple manoeuvres – aerospace materials and structural elements – aircraft instruments.

Elements of rocket propulsion – launch vehicle dynamics – basic orbital mechanics – satellite applications and orbits – future challenges in aerospace engineering.

References:

1. Anderson, D. F. and Eberhardt, S., *Understanding Flight*, 2nd ed., McGraw-Hill (2009).
2. Anderson, J. D., *Introduction to Flight*, 7th ed., McGraw-Hill (2011).
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).

AV111 BASIC ELECTRICAL ENGINEERING (3 – 0 – 0) 3 credits

Circuit analysis, Kirchoff's law, mesh and nodal methods – transient analysis for RLC circuit – alternating current theory – resonance, Q factor and power measurement by two wattmeter circuits – network theorems – magnetic circuit, principles of magnetic circuits – DC and AC excitation – hysteresis loop, BH curve – losses, energy, and force production – Introduction to electrical machines: classification – operating principle – applications.

Textbooks:

1. Hughes, E., *Electrical and Electronic Technology*, Pearson Education (2002).
2. Del Toro, V., *Principles of Electrical Engineering*, 2nd ed., Prentice Hall (1986).

References:

1. Mittle, V. N. and Mittal, A., *Basic Electrical Engineering*, 2nd ed., Tata Mcgraw-Hill (2006).
2. Cotton, H., *Principles of Electrical Engineering*, Sir Isaac Pitman & Sons (1967).
3. Hayt, W. H. and Kemmerley, J. E., *Engineering Circuit Analysis*, 4th ed., McGraw-Hill (1986).
4. Murthy, K. V. V. and Kamath, M. S., *Basic Circuit Analysis*, Jaico Publishing (1998).
5. Kothari, D. P. and Nagrath, I. J., *Theory and Problems of Basic Electrical Engineering*, Prentice Hall (2000).
6. Pal, M. A., *Introduction to Electrical Circuits and Machines*, Affiliated East-West Press (1975).

HS111 COMMUNICATION SKILLS (2 – 0 – 3) 3 credits

Functional English: conversation skills – asking questions, requests, doubts, engage in conversation – different types of communication-verbal and non-verbal, body language.

Teaching Grammar: grammar games, exercise.

Teaching Vocabulary: Language games, exercise.

Reading and appreciating stories, poems, essays – listening and appreciating video lectures – comprehensive questions and answers.

Lab: Presentation skills – appreciation of videos, songs – role plays – debates – extemporizes – group presentations – introduction to technical writing – technical writing, how to write minutes, report, and project proposal.

References:

1. Garner, A., *Conversationally Speaking: Tested New Ways to Increase Your Personal and Social Effectiveness*, McGraw-Hill (1997).
2. Bechtle, M., *Confident Conversation: How to Communicate Successfully in Any Situation*, Revell (2008).
3. Brown, S. and Smith, D., *Active Listening with Speaking*, Cambridge Univ. Press (2007).

PH131 PHYSICS LAB (0 – 0 – 3) 1 credit

- Damped driven oscillator
- Waves and oscillation
- Modulus of elasticity
- Surface tension
- Moment of inertia and angular acceleration
- Faraday’s law of induction
- Biot-Savarts law
- Ratio of electronic charge to mass
- Brewster’s angle and Malu’s law
- Earth’s magnetic field
- Charge of an electron

AE131 BASIC ENGINEERING LAB (0 – 0 – 3) 1 credit

- Study of general purpose hand tools in workshop
- Assembly and disassembly practices of the following models
  - Gear box assembly
  - Centrifugal pump assembly along with shaft alignment practice
  - Cam and follower mechanisms assembly
  - Transducer (sensor) trainer
- Experiments on different basic machines
  - Turning exercise – straight turning, taper turning, thread cutting practice
  - Welding practice – arc welding
  - Fitting practice – models with marking and drilling exercises
- Wiring and Soldering practices

SEMESTER II

MA121 VECTOR CALCULUS AND DIFFERENTIAL EQUATIONS (2 – 1 – 0) 3 credits

Vector Calculus: scalar and vector fields – level surfaces – directional derivatives, gradient, curl, divergence – Laplacian – line and surface integrals – theorems of Green, Gauss, and Stokes.

Sequences and Series of Functions: complex sequences – sequences of functions – uniform convergence of series – test for convergence – uniform convergence for series of functions.

Differential Equations: first order ordinary differential equations – classification of differential equations – existence and uniqueness of solutions of initial value problem – higher order linear differential equations with constant coefficients – method of variation of parameters and method of undetermined coefficients – power series solutions – regular singular point – Frobenius method to solve variable coefficient differential equations.

Special Functions: Legendre polynomials, Bessel's function, gamma function and their properties – Sturm–Liouville problems.

Textbooks:

1. Ross, S. L., *Differential Equations*, Blaisedell (1995).
2. Kreyszig, E., *Advanced Engineering Mathematics*, 10th ed., John Wiley (2011).
3. Stewart, J., *Calculus: Early Transcendentals*, 7th ed., Cengage Learning (2010).

References:

1. Greenberg, M. D., *Advanced Engineering Mathematics*, Pearson Education (2007).
2. Jain, R. K. and Iyengar, S. R. K., *Advanced Engineering Mathematics*, 4th ed., Alpha Science Intl. Ltd. (2013).

MA122 COMPUTER PROGRAMMING AND APPLICATIONS (2 – 0 – 3) 3 credits

Introduction to Linux – introduction to programming – basic elements of a program, variables, values, types, assignment – expressions and control flow – iteration and loop design, arrays, for loop, functions, parameters, recursion – object-oriented paradigm, objects, classes, inheritance, reusability, polymorphism, overloading, libraries, containers, classes for file handling, parameter passing and pointers, linking, shell commands, data structures, linked list, stack, queue – applications.

Textbooks:

1. Lippman, S. B., Lajoie, J., and Moo, B. E., *C++ Primer*, 5th ed., Addison-Wesley (2012).
2. Lafore, R., *Object-Oriented Programming in C++*, 4th ed., Sams Publishing (2001).

References:

1. Cohoon, J. P. and Davidson, J. W., *Programming in C++*, 3rd ed., Tata McGraw-Hill, (2006).
2. Bronson, G., *A First Book of C++*, 4th ed., Cengage (2012).
3. Stroustrup, B., *The C++ Programming Language*, 3rd ed., Pearson (2005).

PH121 PHYSICS II (3 – 1 – 0) 4 credits

Electricity: curvilinear coordinates – conservative vector fields and their potential functions – Gauss' theorem, Stokes' theorem – physical applications in electrostatics – electrostatic potential and field due to discrete and continuous charge distributions – dipole and quadrupole moments – energy density in an electric field – dielectric polarization – conductors and capacitors – electric displacement vector – dielectric susceptibility.

Magnetism: Biot–Savart's law and Ampere's law in magnetostatics – magnetic induction due to configurations of current-carrying conductors – magnetization and surface currents – energy density in a magnetic field – magnetic permeability and susceptibility – force on a charged particle in electric and magnetic fields – electromotive force, Faraday's law of electromagnetic induction – self and mutual inductance, displacement current – Maxwell's equation.

Optics: nature of light – ray approximation in geometrical optics – reflection – refraction, Fermats principle – dispersion – mirrors and lenses – aberrations – interference – diffraction – polarization – lasers.

Textbooks:

1. Griffith, D. J., *Introduction to Electrodynamics*, 4th ed., Prentice Hall (2012).
2. Hecht, E., *Optics*, 4th ed., Pearson Education (2008).

References:

1. Feynman, R. P., Leighton, R. B., and Sands, M., *The Feynman Lectures on Physics*, Narosa (2005).
2. Reitz, J. R., Milford, F. J., and Christy, R. W., *Foundations of Electromagnetic Theory*, 3rd ed., Narosa (1998).
3. Wangsness, R. K., *Electromagnetic Fields*, 2nd ed., Wiley (1986).
4. Sadiku, M. N. O., *Elements of Electromagnetics*, 6th ed., Oxford Univ. Press (2014).

CH121 MATERIALS SCIENCE AND METALLURGY (3 – 0 – 0) 3 credits

Selection of materials – structure of solids, crystal structure – defects in crystals, free energy concept – alloying – principles of solidification – phase diagrams – concept of heat treatment – properties of materials, mechanical, electrical, thermal and optical properties – testing of materials – semiconductor materials – ceramics, synthesis and processing – polymers, classification, mechanism of formation, structure property relations, characterization – composites, classification, factors influencing properties, processing.

Textbooks:

1. Callister Jr., W. D., *Materials Science and Engineering: An Introduction*, 7th ed., John Wiley (2007).
2. Raghavan V., *Physical Metallurgy: Principles and Practice*, 2nd ed., Prentice Hall (2006).

References:

1. Billmeyer, F. W., *Textbook of Polymer Science*, 3rd ed., Wiley India (1984).
2. Askeland, D. R. and Phule, P. P., *The Science and Engineering of Materials*, 4th ed., Thompson-Engineering (2006).

AV121 BASIC ELECTRONICS ENGINEERING (3 – 0 – 0) 3 credits

Semiconductor diode characteristics – applications in rectifiers and power supplies – transistor characteristics.

Biasing circuit – bias stabilization and compensation techniques – small signal low frequency h-parameter model – low frequency transistors.

Amplifiers – FET biasing and low frequency amplifier circuits – RC-coupled amplifiers.

Introduction to operational amplifiers – inverting and non-inverting mode of its operation – digital circuits – Boolean logic – basic gates – truth tables – logic minimization using K maps – combinatorial and sequential circuits.

Textbooks:

1. Boylestad, R. L. and Nashelsky, L., *Electronic Devices and Circuit Theory*, Pearson Education (2003).
2. Mano, M. M., *Digital Design*, Prentice Hall (2002).

References:

1. Mottershed, A., *Electronic Devices and Circuits: An Introduction*, 12th Indian ed., EEE Publication (1989).
2. Bapat, Y. N., *Electronic Devices and Circuits*, 9th ed., Tata McGraw-Hill (1989).

3. Malvino, A. P., *Electronic Principles*, 12th ed., 3rd TMH ed., Tata McGraw-Hill (1989).
4. Jain, R. P., *Modern Digital Electronics*, McGraw-Hill (2004).
5. Floyd, T. L., *Electronic Devices*, 8th ed., Pearson Education (2007).

AE141 — ENGINEERING GRAPHICS — (1 – 0 – 3) 2 credits

Introduction and importance of Engineering Graphics – sheet layout and free-hand sketching – lines, lettering and dimensioning – geometrical constructions – engineering curves – orthographic projection – first angle and third angle projections – projection of points, straight lines and planes – projection of simple solids – sections of solids – development of surfaces – isometric projection – introduction to AutoCAD – creation of simple 2D drawings.

Textbook:

- Bhatt, N. D., *Engineering Drawing: Plane and Solid Geometry*, 50th ed., Charotar Publishing House (2010).

References:

1. Jolhe, D. A., *Engineering Drawing with an Introduction to AutoCAD*, Tata McGraw-Hill (2008).
2. Venugopal, K. and Prabhu Raja, V., *Engineering Drawing + AutoCAD*, 5th ed., New Age International (2011).
3. Varghese, P. I., *Engineering Graphics for Degree including AutoCAD*, VIP Publishers (2012).
4. Luzadder, W. J. and Duff, J. M., *Fundamentals of Engineering Drawing*, 11th ed., Prentice Hall (1992).
5. Bethune, J. D., *Engineering Graphics with AutoCAD*, Prentice Hall, 2007.

CH141 — CHEMISTRY LAB — (0 – 0 – 3) 1 credit

- Determination of total hardness of water
- The Nernst equation
- Potentiometry
- Conductometry
- Determination of phosphoric acid content in soft drink
- Determination of chloride content in water
- Validation of Ostwald's dilution law and solubility product
- Kinetics of acid hydrolysis of ester
- Kinetics of sucrose inversion

- Preparation of polymers
- Determination of molecular weight of polymers
- Metallography of steels
- Microhardness of different materials

AV141 BASIC ELECTRICAL AND ELECTRONICS ENGINEERING LAB (0 – 0 – 3) 1 credit

- Electrical Engineering Lab
  - Magnetic measurements
  - Three phase power measurement
  - Verification of theorems
  - Characteristic of electrical machines (AC and DC)
- Electronics Engineering Lab
  - Implementation of digital circuits
  - Design of electronic system using operational amplifiers
  - Device characteristic
  - Power supply design
  - Wave shaping circuits: clippers and clampers
  - Biasing of transistor

SEMESTER III

MA211 LINEAR ALGEBRA, NUMERICAL ANALYSIS AND TRANSFORMS (3 - 0 - 0) 3 credits

Linear Algebra: matrices; solution space of system of equations $Ax = b$, eigenvalues and eigenvectors, Cayley-Hamilton theorem – Definition of Group, ring field – Vector spaces over real field, subspaces, linear dependence, independence, basis, dimension – inner product – Gram–Schmidt orthogonalization process – linear transformation; null space and nullity, range and rank of a linear transformation.

Numerical Methods: solution of algebraic and transcendental equations – solution of system of linear equations – numerical integration – interpolation – solution of ordinary differential equations.

Transforms: Fourier series expansion of periodic functions with period two – Fourier series of even and odd functions – half-range series – Fourier series of functions with arbitrary period – conditions of convergence of Fourier series. Fourier integral – the Fourier transform pair – algebraic properties of Fourier transform – convolution, modulation, and translation – transforms of derivatives and derivatives of transform – inversion theory. Laplace transforms of elementary functions – inverse Laplace transforms – linearity property – first and second shifting theorem – Laplace transforms of derivatives and integrals – Laplace transform of Dirac delta function – applications of Laplace transform in solving ordinary differential equations.

Textbooks:

1. Kreyszig, E., *Advanced Engineering Mathematics*, 10th ed., John Wiley (2011).
2. Jain, M. K., Iyengar, S. R. K., and Jain, R. K., *Numerical Methods for Scientific and Engineering Computation*, 4th ed., New Age International (2005).

References:

1. Greenberg, M. D., *Advanced Engineering Mathematics*, Pearson Education (2007).
2. Conte, S. D. and de Boor, C., *Elementary Numerical Analysis*, 3rd ed., Tata McGraw-Hill (2005).
3. Krishnamurthy, K. V., *Numerical Algorithms*, Affiliated East-West Press (1986).
4. Jain, R. K. and Iyengar, S. R. K., *Advanced Engineering Mathematics*, 4th ed., Alpha Science Intl. Ltd. (2013).

AE211 ENGINEERING THERMODYNAMICS (3 – 0 – 0) 3 credits

Introduction to applications – basic concepts and definitions – thermodynamic properties of pure substances – saturated and other states – work and heat, definition and applications – first law, internal energy and enthalpy, applications to non-flow and flow systems – second law, corollaries, Clasius inequality, entropy – availability, irreversibility and exergy – thermodynamic cycles – basics of gas-vapor mixtures and reacting systems – thermodynamic relations – combustion thermodynamics, stoichiometry, first, second, and third laws of thermodynamics applied to combustion.

Textbook:

- Çengel, Y. A. and Boles, M. A., *Thermodynamics – An Engineering Approach*, 5th ed., Tata McGraw-Hill (2006).

References:

1. Nag, P. K., *Engineering Thermodynamics*, 3rd ed., Tata McGraw-Hill (2005).
2. Moran, M. J. and Shapiro, H. N., *Fundamentals of Engineering Thermodynamics*, 6th ed., Wiley (2007).
3. Borgnakke, C. and Sonntag, R. E., *Fundamentals of Thermodynamics*, 7th ed., Wiley (2009).

AE212 MECHANICS OF SOLIDS (3 – 0 – 0) 3 credits

Concepts of stress, strain – torsion – axial force, shear, and bending moment – pure bending – shear stress in beams – transformation of stresses and strains – deflection of beams – columns; Euler loads, beam-columns, eccentrically loaded columns – energy methods, virtual displacement method, virtual force method.

Textbook:

- Popov, E. P., *Engineering Mechanics of Solids*, 2nd ed., Prentice Hall (1998).

References:

1. Hibbeler, R. C., *Mechanics of Materials*, 6th ed., Prentice Hall (2004).
2. Beer, F. P., Johnston, E. R., and DeWolf, J. T., *Mechanics of Materials*, 4th ed., McGraw-Hill (2005).
3. Srinath, L. S., *Advanced Mechanics of Solids*, 2nd ed., Tata McGraw-Hill (2003).

AE213 FLUID MECHANICS (3 – 0 – 0) 3 credits

Fluid properties – fluid statics – integral control volume formulation – applications of Bernoulli equation – fluid kinematics – differential formulation, continuity and momentum equations – exact solutions of Navier–Stokes equation – dimensional analysis – pipe flow – potential flow – boundary layer theory.

Textbook:

- White, F. M., *Fluid Mechanics*, 7th ed., McGraw-Hill (2011).

References:

1. Pritchard, P. J., *Fox and McDonald's Introduction to Fluid Mechanics*, 8th ed., John Wiley (2011).
2. Çengel, Y. A. and Cimbala, J. M., *Fluid Mechanics: Fundamental and Applications*, 2nd ed., McGraw-Hill (2010).
3. Munson, B. R., Young, D. F., Okiishi, T. H., and Huebsch, W. W., *Fundamentals of Fluid Mechanics*, 6th ed., John Wiley (2009).

AE214 MANUFACTURING TECHNOLOGY (3 – 0 – 0) 3 credits

Ferrous and nonferrous alloys – introduction to dislocations and defects – diffusion – strengthening mechanisms – iron carbon diagram – steels and its heat treatment processes.

Metal casting – basic system design – processes and equipments – metal forming – processes and systems – concept of hot, cold and warm working – yield criteria – free upsetting and fastener manufacturing – welding techniques – processes and equipments – fusion and solid state welding – brazing & soldering – defects in casting, forming, welding – inspection & NDT.

Basics of powder metallurgy – introduction to additive manufacturing.

Textbook:

- Kalpakjian, S. and Schmidt, S. R., *Manufacturing Engineering and Technology*, Pearson Education (2009).

References:

1. Ghosh, A. and Mallik, A. K., *Manufacturing Science*, Affiliated East West Press (2010).
2. Beddoes, J. and Bibby, M. J., *Principles of Metal Manufacturing Processes*, Butterworth-Heinemann (1999).
3. Abbaschian, R., Abbaschian, L., and Reed-Hill, R. E., *Physical Metallurgy Principles*, 4th ed., Cengage Learning (2008).

HS211 INTRODUCTION TO ECONOMICS (2 – 0 – 0) 2 credits

Exploring the Subject Matter of Economics: why we study economics – types - definitions – economic systems – economics as a science.

Principles and Concepts of Micro Economics: demand – supply – production – costs – markets – equilibrium.

Basics of Macro Economics: role of government – national income concepts – inflation concepts – classical vs. Keynesianism.

Economic Problems and Policies: meaning of development – problems of growth – population – agriculture and industry – balance of payments – planning – study report related to economics of space program.

Textbooks:

1. Samuelson, P. A. and Nordhaus, W. D., *Economics*, 18th ed., McGraw-Hill (2005).
2. Dewett, K. K., *Modern Economic Theory*, 22nd ed., S. Chand (2005).
3. Thirlwall, A. P., *Growth and Development with Special Reference to Developing Economies*, 7th ed., Palgrave Macmillan (2003).

References:

1. Gardner, A., *Macroeconomic Theory*, Surjeet Publications (1998).
2. Koutsoyiannis, A., *Modern Microeconomics*, 2nd ed., Palgrave Macmillan (2003).
3. Black, J., *A Dictionary of Economics*, Oxford Univ. Press (2003).
4. Meir, J. M. and Rauch, J. E., *Leading Issues in Economic Development*, 7th ed., Oxford Univ. Press (2005).
5. Todaro, M. P. and Smith, S. C., *Economic Development*, 8th ed., Pearson Education Ltd. (2008).
6. *Economic Survey 2008*, Government of India, Ministry of Finance.
7. O'Connor, D. E., *The Basics of Economics*, Greenwood Press (2004).

AE231 MACHINE DRAWING (1 – 0 – 3) 2 credits

Sectioning and dimensioning – introduction to limit, fits and tolerances – understanding the selection and functions of machine elements in engineering sub assemblies/assemblies – computer aided drafting of machine elements – understanding and preparation of shop floor drawings – solid modelling – introduction to solid modellers – solid modelling of various machine parts – simple design exercise/project.

References:

1. Narayana, K. L., Kannaiah, P., and Venkata Reddy K., *Machine Drawing*, 4th ed., New Age International (2010).
2. Ajeet Singh, *Machine Drawing: Includes AutoCAD*, 2nd ed., Tata McGraw-Hill (2012).
3. John, K. C., *Textbook of Machine Drawing*, PHI Learning (2009).
4. Junnarkar, N. D., *Machine Drawing*, Pearson Education (2007).
5. Bhatt, N. D. and Panchal, V. M., *Machine Drawing*, 49th ed., Charotar Publishing (2014).
6. Sidheswar, N., Kanniah, P., and Sastry, V. V. S., *Machine Drawing*, Tata McGraw-Hill (2001).

AE232 STRENGTH OF MATERIALS LAB (0 – 0 – 3) 1 credit

- Tension tests: mild steel and aluminium alloy rods
- Hardness tests: Brinell hardness, Vickers hardness, Rockwell hardness
- Impact tests: Izod and Charpy tests
- Torsion test
- Double shear test
- Compression test
- Spring test
- Deflection of beams

SEMESTER IV

MA221 PDE, CALCULUS OF VARIATIONS, AND COMPLEX ANALYSIS (3 – 0 – 0) 3 credits

Partial Differential Equations: introduction to PDEs – modeling Problems related and general second order PDE – classification of PDE: hyperbolic, elliptic and parabolic PDEs – canonical form – scalar first order PDEs – method of characteristics – Charpits method – quasi-linear first order equations – shocks and rarefactions – solution of heat, wave, and Laplace equations using separable variable techniques and Fourier series.

Calculus of Variations: optimization of functional – Euler–Lagrange equations – first variation – isoperimetric problems – Rayleigh–Ritz method.

Complex Variable: complex numbers and their geometrical representation – functions of complex variable – limit, continuity and derivative of functions of complex variable – analytical functions and applications – harmonic functions – transformations and conformal mappings – bilinear transformation – contour integration and Cauchys theorem – convergent series of analytic functions – Laurent and Taylor series – zeroes and singularities – calculation of residues – residue theorem and applications.

Textbooks:

1. Kreyszig, E., *Advanced Engineering Mathematics*, 10th ed., John Wiley (2011).
2. Mathews, J. H. and Howell, R., *Complex Analysis for Mathematics and Engineering*, Narosa (2005).

References:

1. Churchill, R. V. and Brown, J. W., *Complex Variables and Applications*, 6th ed., McGraw-Hill (2004).
2. Wylie, C. R. and Barrett, L. C., *Advanced Engineering Mathematics*, McGraw-Hill (2002).
3. Greenberg, M. D., *Advanced Engineering Mathematics*, Pearson Education (2007).
4. James, G., *Advanced Modern Engineering Mathematics*, 3rd ed., Pearson Education (2005).
5. Sneddon, I. N., *Elements of Partial Differential Equations*, McGraw-Hill (1986).
6. Renardy, M. and Rogers, R. C., *An Introduction to Partial Differential Equations*, 2nd ed., Springer-Verlag (2004).
7. McOwen, R. C., *Partial Differential Equations: Methods and Applications*, 2nd ed., Pearson Education (2003).
8. Borelli, R. L., *Differential Equations: A Modelling Perspective*, 2nd ed., Wiley, 2004.

AE221 GAS DYNAMICS (3 – 0 – 0) 3 credits

Governing equations – static and stagnation properties – speed of sound and Mach number – isentropic flow through variable area ducts – normal and oblique shocks – expansion waves – Fanno flow – Rayleigh flow – Prandtl-Meyer flow – small perturbations theory – unsteady wave motion.

Textbook:

- Anderson, J. D., *Modern Compressible Flow with Historical Perspective*, 3rd ed., McGraw-Hill (2004).

References:

1. Zucker, R. D. and Biblarz, O., *Fundamentals of Gas Dynamics*, 2nd ed., John Wiley (2002).
2. John, J. E. A. and Keith, T., *Gas Dynamics*, 3rd ed., Prentice Hall (2006).
3. Yahya, S. M., *Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion*, 3rd ed., New Age International Publishers (2003).

AE222 HEAT TRANSFER (3 – 0 – 0) 3 credits

Introduction to heat transfer – steady state heat conduction – transient heat conduction – introduction to convective heat transfer – external forced convection – internal forced convection – natural/free convection – heat exchangers – black-body radiation and radiative properties – radiative exchange between surfaces.

Textbook:

- Incropera, F. P. and DeWitt, D. P., *Fundamentals of Heat and Mass Transfer*, 5th ed., John Wiley (2002).

References:

1. Holman, J. P., *Heat Transfer*, 9th ed., Tata McGraw-Hill (2007).
2. Çengel, Y. A., *Heat and Mass Transfer: A Practical Approach*, 3rd ed., Tata McGraw-Hill (2006).

AE223 KINEMATICS AND DYNAMICS OF MECHANISMS (3 – 1 – 0) 4 credits

Review of joints and mobility, position, velocity and acceleration analysis of linkages – cams, gears, and gear trains – static and dynamic analysis of mechanisms – gyroscopes – balancing – single degree of freedom systems – free and forced vibration – multi degrees of freedom systems – natural frequencies, modes.

Textbook:

- Uicker, J. J., Pennock, G. R., and Shigley, J. E., *Theory of Machines and Mechanisms*, 3rd ed., Oxford Univ. Press (2003).

References:

1. Rattan, S. S., *Theory of Machines*, 2nd ed., Tata McGraw-Hill (2005).
2. Myszka, D. H., *Machines and Mechanisms: Applied Kinematics Analysis*, 3rd ed., Prentice Hall (2004).

AE224 METROLOGY AND COMPUTER AIDED INSPECTION (3 – 0 – 0) 3 credits

Introduction to metrology, fundamentals of dimensional measurements, length standards, application of light interference for precision measurements – fits and tolerances – concepts and practices of gauging – comparators and their applications – linear and angular measurements – thread and gear inspection – form, flatness, straightness, and alignment measurements – surface metrology – co-ordinate metrology – laser applications in metrology – vision inspection – micro- and nano-metrology.

Textbooks:

1. Shotbolt, C. S. and Galyer, J., *Metrology for Engineers*, 5th ed., Cassell Pub. (1990).
2. Jain, R. K., *Engineering Metrology*, Khanna Pub. (2008).
3. Busch, T., *Fundamentals of Dimensional Metrology*, Delmar Pub. (1988).

References:

1. Smith, G. T., *Industrial Metrology: Surfaces and Roundness*, Springer-Verlag (2002).
2. Whitehouse, D. J., *Handbook of Surface Metrology*, Taylor & Francis (1994).

HS221 INTRODUCTION TO SOCIAL SCIENCE AND ETHICS (2 – 0 – 0) 2 credits

Social Science: introduction to sociology, anthropology – social science research design and sampling.

Ethics: professional and personal ethics – values & norms and human rights.

Textbooks:

- Lecture Notes

References:

1. Perry, J. and Perry, E., *Contemporary Society: An Introduction to Social Science*, 11th ed., Allyn & Bacon (2005).

2. Giddens, A., *Sociology*, 5^{th} ed., Wiley (2006).
3. Flyvbjerg, B., *Making Social Science Matter*, Cambridge Univ. Press (2001).
4. Singer, P., *A Companion to Ethics*, Wiley-Blackwell (1993).

AE241 THERMAL AND FLUID LAB (0 – 0 – 6) 2 credits

- Fluid Mechanics
  - Calibration of venturi and orifice meters
  - Characterization of friction loss in pipe flow
  - Performance test on centrifugal pump
  - Performance test on Francis turbine
  - Performance test on Pelton turbine
  - Performance test on reciprocating pump
  - Experiments on transition in pipe flows
- Heat Transfer
  - Evaluation of heat transfer coefficient and thermal conductivity of materials
  - Experiments on forced and natural convection apparatus
  - Performance test on plate heat exchanger
  - Laws on radiant heat transfer and heat exchange
  - Experiments on transient conduction
  - Pin-fin apparatus
- Thermal Engineering
  - Performance test on reciprocation compressor
  - Performance test on centrifugal blower
  - Performance test on vapour compression refrigeration unit
  - Load test on single cylinder diesel engine
  - Performance test on a multi-cylinder MPFI gasoline engine
  - Performance test on heat pump unit

SEMESTER V

MA311 PROBABILITY AND STATISTICS (3 – 0 – 0) 3 credits

Probability Distributions: binomial distribution, hyper geometric distribution – Poisson approximation to the binomial, geometric distribution, normal distribution – normal approximation to the binomial distribution, uniform distribution, gamma distribution, beta distribution, and Weibull distribution – mathematical expectation and moments, mean, variance, moment generating function, and characteristic function – random Variable, discrete and continuous random variables.

Sampling Distributions and Inference Concerning Means: population and samples – central limit theorem – sampling distributions of mean and variance – point estimation – confidence interval for mean, variance and proportions – tests of hypotheses, the null hypotheses and the significance tests – control charts for variables and attributes – acceptance sampling by attributes – simple, double and sequential sampling plans – design of experiments.

Correlation and Regression Analysis: curve fitting by the method of least squares – Chi-square test of goodness of fit – contingency tables – inference based on the least square estimators – regression – correlation – inference concerning correlation coefficient.

Textbook:

- Walpole, W. E., Myers, R. H., Myers, S. L., and Ye, K., *Probability & Statistics for Engineers & Scientists*, 9th ed., Pearson Education (2012).

References:

1. Johnson, R. A., *Miller & Freund's Probability and Statistics for Engineers*, 6th ed., Prentice Hall (2000).
2. Levin, R. I. and Rubin, D. S., *Statistics for Management*, 7th ed., Prentice Hall (1998).
3. Milton, J. S. and Arnold, J. C., *Introduction to Probability and Statistics: Principles and Applications for Engineering and the Computing Sciences*, McGraw-Hill (2002).
4. Ross, S. M., *Introduction to Probability and Statistics for Engineers and Scientists*, 3rd ed., Academic Press (2004).
5. Feller, W., *An Introduction to Probability Theory and Its Applications*, Vol. 1 & Vol. 2, John Wiley (1968).
6. Hogg, R. V., Craig, T., and McKean, J. W., *Introduction to Mathematical Statistics*, 6th ed., Prentice Hall (2004)
7. Hogg, R. V. and Tanis, E. A., *Probability and Statistical Inference*, 7th ed., Prentice Hall (2005).
8. Larsen, R. J. and Marx, M. L., *An Introduction to Mathematical Statistics and Its Applications*, 4th ed., Prentice Hall (2005).

9. Mendenhall, W., Wackerly, D., and Scheaffer, R. L., *Mathematical Statistics with Applications*, 7th ed., Duxbury Press (2007).

AE311 — AERODYNAMICS — (3 – 0 – 0) 3 credits

Fundamental aerodynamic variables – inviscid, incompressible flows – elementary flows – non-lifting and lifting flows over cylinders – Kutta–Joukowski theorem – airfoil nomenclature and characteristics – incompressible flow past airfoils – starting vortex – classical thin airfoil theory – symmetrical and cambered airfoils – incompressible flow past finite wings – vortex filament and sheet – Biot–Savart law – Prandtls lifting line theory – elements of vortex panel method – viscous flow over wings – rocket aerodynamics.

Textbook:

- Anderson, J. D., *Fundamentals of Aerodynamics*, 4th ed., McGraw-Hill (2006).

References:

1. Bertin, J. J. and Cummings, R. M., *Aerodynamics for Engineers*, 5th ed., Prentice Hall (2008).
2. Kuethe, A. M. and Chow, C.-Y., *Foundations of Aerodynamics*, 5th ed., John Wiley (1997).
3. Clancy, L. J., *Aerodynamics*, Reprint ed., Himalayan Books (2006).
4. Nielsen, J. N., *Missile Aerodynamics*, AIAA (1988).

AE312 — AEROSPACE STRUCTURES I — (3 – 1 – 0) 4 credits

Introduction to theory of elasticity – linear and nonlinear strain descriptions – stress-strain relations – thermal stresses – isotropic and orthotropic materials – introduction to laminated composites – stress functions – torsion of solid sections – theory of thin plates and axisymmetric shells – structural instability – virtual work, energy and matrix methods – introduction to finite element method.

Textbook:

- Megson, T. H. G., *Aircraft Structures for Engineering Students*, 4th ed., Butterworth-Heinemann (2007).

References:

1. Timoshenko, S. P. and Goodier, J. N., *Theory of Elasticity*, 3rd ed., McGraw-Hill (1970).
2. Timoshenko, S. P. and Woinowsky-Krieger, S., *Theory of Plates and Shells*, 2nd ed., McGraw-Hill (1964).
3. Osgood, C. C., *Spacecraft Structures*, Prentice Hall (1966).

AE313 MANUFACTURING TECHNOLOGY II (3 – 0 – 0) 3 credits

Principles of Metal Cutting: mechanics of metal cutting – cutting tools – cutting processes – process variables – tool life.

Abrasive Machining Processes: Grinding – fine finishing process.

Machine Tools: conventional machine tool configuration – CNC technology – CNC machine tools and programming.

Nontraditional Machining: principles, equipment, process variables and applications – surface engineering – concept of CIM and FMS – additive manufacturing – advanced manufacturing techniques.

Textbooks:

1. Groover, M. P., *Fundamentals of Modern Manufacturing: Materials, Processes, and Systems*, 4th ed., Wiley India (2010).
2. Kalpakjian, S. and Schmidt, S. R., *Manufacturing Engineering and Technology*, Pearson Education (2009).

References:

1. Pandey, P. C. and Shah, H. S., *Modern Machining Processes*, Tata McGraw-Hill, 1988.
2. Juneja, B. L., Sekhon, G. S., and Seth, N., *Fundamentals of Metal Cutting and Machine Tools*, New Age International (2008).

AV315 INSTRUMENTATION AND CONTROL SYSTEMS (3 – 0 – 0) 3 credits

Instrumentation: sensitivity, linearity, and resolution of instruments – uncertainty of measurements – signal conditioners - bridge circuits, amplifiers, and filters – measurement of displacement, velocity, acceleration, force, torque, pressure, flow, temperature, and level.

Control Systems: classification of control systems – block diagram representation and reductions – mathematical background and mathematical model of physical systems – time domain analysis, transient response, and stability – frequency response methods, polar plot, bode diagrams, Nyquist stability criteria.

Controllers: types of controllers – types of control action; proportional, integral, derivative, on-off controls – hydraulic, electronic, and pneumatic controllers.

Textbooks:

1. D'Azzo, H., *Feedback Control System Analaysis and Synthesis*, CRC Press (2007).
2. Rangan, C. S., Sharma, G. R., and Mani, V. S. V., *Instrumentation: Devices and Systems*, 2nd ed., Tata McGraw-Hill (2006).

References:

1. Astrom, K. J. and Murray, R. M., *Feedback Systems: An Introduction for Scientists and Engineers*, Princeton Univ. Press (2008).
2. Nise, N. S., *Control Systems Engineering*, 4th ed., Wiley India (2003).
3. Xue, D., Chen, YQ., and Atherton, D. P., *Linear Feedback Control Analysis and Design with MATLAB*, SIAM (2007).
4. Gopal, M., *Control Systems: Principles and Design*, 3rd ed., Tata McGraw-Hill (2008).
5. Doebelin, E. O., *Measurement Systems: Application and Design*, 5th ed., McGraw-Hill (2003).

CH311 ENVIRONMENTAL SCIENCE AND ENGINEERING (2 – 0 – 0) 2 credits

Awareness of the impact of environment on quality of life – natural resources – biological systems – bio-geo chemical cycles – chemical processes; water treatment operations, water sampling, storage, quality measurement – oxygen demand – detection of pollutants – current environmental issues; pollutants, global warming, causes and consequences, air pollution, organic and inorganic air pollutants, smog-acid mine drainage, accumulation of salts in water – soil formation; micro and macro nutrients in soil, pollutants in soil – green chemistry- an alternative tool for reducing pollution – engineering interventions; flow sheets, waste minimization, e-waste management, ASP, reverse osmosis, trickling filter – environmental management; solid, liquid waste management, hazardous wastes, ISO standards – Kyoto protocol, Montreal protocol, Euro norms.

Textbook:

- Rao, V., *Textbook of Environmental Engineering*, Prentice Hall of India (2002).

References:

1. Baird, C. and Cann, M., *Environmental Chemistry*, 3rd ed., W. H. Freeman and Company (2005).
2. *Manual on Water Supply and Treatment*, CPHEEO, Ministry of Urban Development, GOI (1999).
3. *Manual on Sewerage and Sewage Development*, CPHEEO, Ministry of Urban Development, GOI (1993).
4. Hauser, B. A., *Practical Hydraulics Hand Book*, Lewis Pub. (1991).
5. Hammer, M. J., *Water and Wastewater Technology*, Regents/Prentice Hall (1991).
6. Sharma, J. P., *Comprehensive Environmental Studies*, Laxmi Pub. (2004).
7. Garg, S. K., *Environmental Engineering* (Vol. 1 & Vol. 2), Khanna Pub. (2004).
8. Kiely, G., *Environmental Engineering*, McGraw-Hill (1997).
9. Bharucha, E., *Textbook of Environmental Studies*, University Grants Commission (2004).

10. Vanloon, G. W. and Duffy, S. J., *Environmental Chemistry: A Global Perspective*, Oxford Univ. Press (2000).

AE331 AERODYNAMICS LAB (0 – 0 – 3) 1 credit

- Calibration of wind tunnel
- Boundary layer measurements
- Flow visualization over a cambered aerofoil
- Pressure distribution over a symmetric aerofoil
- Wake survey over a cylinder
- Flow through a bent tube
- Oil flow and tuft flow visualization
- Drag measurements on a cylinder using strain gauge balance
- Interference study between two cylinders

AE332 METROLOGY LAB (0 – 0 – 3) 1 credit

- Dimensional measurement using minor measuring instruments
- Measurement of angle using Sine bar and digital angle protractor
- Dimensional measurement using profile projector
- Measurement of screw thread parameters using tool maker's microscope
- Measurement of pitch diameter of thread plug gauge and diameter of plain plug gauges on universal length measuring machine.
- Experiment to study the relationship between pressure and gap thickness on the air gauge system and demonstration of diameter measurement of the given specimen
- Dimensional measurement using digital height gauge
- Determination of calibration uncertainty of micrometer/dial indicator/electronic probes using slip gauges/universal length measuring machine
- Experiment on statistical quality control ($\overline{X}$ and R chart) and process capability analysis
- Straightness error measurement using autocollimator
- Flatness measurement of surface plate using electronic levels
- Roughness measurement on specimens machined by various operations
- Measurement of dimensions using vision inspection system
- Study of alignment telescope

AV335 INSTRUCTIONS AND CONTROL SYSTEMS LAB (0 – 0 – 3) 1 credit

- Familiarization with MATLAB and SIMULINK
- Compensator design for a typical electromechanical engine gimbal control (EGC) system and linear system performance assessment using MATLAB/SIMULINK
- Evaluation of step response, frequency response and disturbance response of the nonlinear model of electromechanical engine gimbal control (EGC) system using MATLAB/SIMULINK
- Nonlinear model simulation of an aircraft elevon surface actuation system

SEMESTER VI

AE321 ATMOSPHERIC FLIGHT MECHANICS (3 – 1 – 0) 4 credits

Overview of aerodynamics, propulsion, atmosphere and aircraft instrumentation – frames of reference – body axis, wind axis, earth centric, inertial – equations of motion in non-rotating earth and flat-earth frames of reference – aircraft performance – gliding, cruise and climbing flight, optimal cruise trajectories, take-off and landing – V-n diagrams – static longitudinal, directional, and lateral stability and control – stick fixed and stick free stability, hinge moments, trim-tabs, aerodynamic balancing – effect of manoeuvres – aerodynamic modelling, simulation, concept of steady states, linearisation, decoupling of longitudinal and lateral/directional motion – dynamic stability, longitudinal motion and short period and phugoid modes, lateral/directional motion, spiral, divergence, roll subsidence and dutch roll modes – stability, control and performance characteristics of sounding rockets and launch vehicles.

Textbooks:

1. Hull, D. G., *Fundamentals of Airplane Flight Mechanics*, Springer (2007).
2. Perkins, C. D. And Hage, R. E., *Airplane Performance Stability & Control*, John Wiley (1949).

References:

1. Etkin, B., *Dynamics of Flight*, John Wiley (1989).
2. McCormick, B. W., *Aerodynamics, Aeronautics, and Flight Dynamics*, 2nd ed., John Wiley (1994).
3. Pamadi, B. N., *Performance, Stability, Dynamics, and Control of Airplanes*, 2nd ed., AIAA Edu. Series (2004).
4. Smetana, F. O., *Flight Vehicle Performance and Aerodynamic Control*, AIAA Edu. Series (2001).

AE322 SPACEFLIGHT MECHANICS (3 – 0 – 0) 3 credits

Dynamics of Particles: reference frames and rotations – energy, angular momentum.

Two Body Motion: equations of motion – Kepler laws – solution to two-body problem – conics and relations – vis-viva equation Kepler equation – orbital elements – orbit determination – Lambert problem – satellite tracking.

Non-Keplerian Motion: perturbing acceleration – earth aspherical potential – oblateness – third body effects – atmospheric drag effects – application of perturbations.

Orbit Maneuvers: Hohmann transfer – inclination change maneuvers, combined maneuvers, bi-elliptic maneuvers.

Lunar / Interplanetary Trajectories: sphere of influence – methods of trajectory design – restricted three body problem – Lagrangian points.

Rigid Body Dynamics: attitude control of spinning and non-spinning spacecrafts.

Textbooks:

1. Curtis, H. D., *Orbital Mechanics for Engineering Students*, 2nd ed., Elsevier (2009).
2. Chobotov, V. A., *Orbital Mechanics*, 3rd ed., AIAA Edu. Series (2002).
3. Wiesel, W. E., *Spaceflight Dynamics*, 2nd ed., McGraw-Hill (1996).

References:

1. Brown C. D., *Spacecraft Mission Design*, 2nd ed., AIAA Edu. Series (1998).
2. Escobal, P. R., *Methods of Orbit Determination*, 2nd ed., Krieger Pub. Co. (1976).
3. Tewari, A., *Atmospheric and Space Flight Dynamics: Modeling and Simulation with MATLAB and Simulink*, Birkhuser (2007).

AE323 AIR-BREATHING PROPULSION (3 – 0 – 0) 3 credits

Review of combustion and flames – introduction to air breathing propulsion systems – review of basic gas dynamics equations – types of nozzles – design and operating characteristics – aircraft engine types – performance measures – fundamentals of aircraft gas turbine engine cycles – engine components and configurations – working performance evaluation – design and off design performance – basics of turbomachinery– compressor and turbine blade flow path analysis (centrifugal and axial types) – hypersonic air breathing engines – ramjet and scramjet – combustion systems.

Textbooks:

1. Hill, P. G. and Peterson, C. R., *Mechanics and Thermodynamics of Propulsion*, 2nd ed., Addison-Wesley (1992).
2. Mattingly, J. D., *Elements of Propulsion: Gas Turbines and Rockets*, AIAA Edu. Series, 2006.

References:

1. Flack, R. D., *Fundamentals of Jet Propulsion with Applications*, Cambridge Univ. Press (2005).
2. Mattingly, J. D., *Elements of Gas Turbine Propulsion*, AIAA Edu. Series (2005).
3. Heiser, W. H. and Pratt, D. T., *Hypersonic Air Breathing Propulsion*, AIAA Edu. Series (1994).

AE324 AEROSPACE STRUCTURES II (3 – 1 – 0) 4 credits

Description of essential features of aircraft, rocket and spacecraft structures – type of loads on flight structures – bending, shear and torsion of open and closed thin-walled beams – monocoque, stiffened plate, isogrid and sandwich constructions – idealization and stress analysis of typical aerospace structural components – pressurized structures – stress discontinuities – effects of cut-outs – effects of boundary conditions in open and closed section beams – structural fatigue.

Textbook:

- Megson, T. H. G., *Aircraft Structures for Engineering Students*, 4th ed., Butterworth-Heinemann (2007).

References:

1. Timoshenko, S. P. and Goodier, J. N., *Theory of Elasticity*, 3rd ed., McGraw-Hill (1970).
2. Timoshenko, S. P. and Woinowsky-Krieger, S., *Theory of Plates and Shells*, 2nd ed., McGraw-Hill (1964).
3. Bruhn, E. F., *Analysis and Design of Flight Vehicle Structures*, 2nd ed., Jacobs Publishing Inc. (1973).

E01 *ELECTIVE I* (3 – 0 – 0) 3 credits

HS321 PRINCIPLES OF MANAGEMENT SYSTEMS (3 – 0 – 0) 3 credits

Personnel Management: introduction – changing role of personnel manager – new people management – manpower planning – recruitment and selection – performance appraisal – workers participation in management – grievance handling.

Industrial Management: management functions – organization – principles of planning – management by objectives – organization structures – principles of organizing – span of control – delegation, leadership, directing, and controlling.

Project Management: development of project network – project representation – project scheduling – linear time-cost trade-offs in projects: a heuristic approach – project monitoring and control with PERT.

References:

1. Koontz H., ODonnel, C., and Weihrich, H., *Essentials of Management*, McGraw-Hill (1990).
2. Venkataratnam, C. S. and Srivastava, B. K., *Personnel Management and Human Resources*, Tata McGraw-Hill (1991).

3. Mazda F., *Engineering Management*, Prentice Hall (1997)
4. Gido, J. and Clements, J. P., *Successful Project Management*, 2nd ed., South-Western College Publishing (2003)
5. Khanna, O. P., *Industrial Engineering and Management*, Dhanpat Rai Publications (P) Ltd. (2003).
6. Memoria, C. B. and Gankar, S. V., *Personnel Management – Text and Cases*, Himalaya Publishing House (2007).

AE341 AEROSPACE STRUCTURES LAB (0 – 0 – 3) 1 credit

- Buckling of struts
- Experiments on thin-walled pressure vessel
- Unsymmetrical bending and shear center measurements
- measurement of strain using strain gauges
- Shear force in a beam
- Deflection of beams and cantilevers
- Continuous and indeterminate beams
- Uniaxial tension test with loading/unloading

AE342 MANUFACTURING PROCESSES LAB (0 – 0 – 3) 1 credit

- Study and simulation practices of CNC turning and milling experiments using Fanuc system
- Experiments in CNC turning machine
- Experiments in CNC milling machine
- Assessment of surface finish on surface grinding
- Metallographic study near the weld zone of the TIG weld piece
- Assessment of surface finish on cylindrical grinding
- Electric discharge machining process – material removal rate and over cut measurement
- Demonstration of rapid prototyping machine
- Demonstration of Turn Mill centre
- Demonstration of cutting force measurements during machining process using dynamometer
- Demonstration of different robots and flexible manufacturing system

AE343 MODELING AND ANALYSIS LAB (0 – 0 – 3) 1 credit

- Modeling using Catia and Inventor
  - Create assembly of different mechanisms and components like slider crank mechanism, double riveted lap joint, protected flanged coupling using Catia
  - Conduct dynamic simulation of different mechanisms like slider crank mechanism, double pendulum, simple robotic mechanism, cam & follower mechanism using Inventor
- Modeling and analysis using FEM
  - Geometric modeling and finite element meshing of beam, plate, and solid structures
  - Stress analysis of plate and beam structures
  - Free vibration analysis of plate and beam structures
- Modeling and simulation of multi-rigid body systems using Scilab/MATLAB

SEMESTER VII

AE411 ROCKET PROPULSION (3 – 0 – 0) 3 credits

Introduction to rocket propulsion systems – rocket propulsion engines – types of rocket nozzles and thrust vector control – propellants – combustion in rocket engines – parameters for chemical rockets – elements of liquid propulsion systems – thrust chambers – turbo pumps – nonconventional propulsion techniques – solid rocket motors – grain configuration – hybrid rockets – rocket testing and performance evaluation – selection of rocket motors.

Textbook:

- Sutton, G. P. and Biblarz, O., *Rocket Propulsion Elements*, 7th ed., John Wiley (2000).

References:

- Hill, P. G. and Peterson, C. R., *Mechanics and Thermodynamics of Propulsion*, 2nd ed., Addison-Wesley (1992).
- Ramamurthi, K., *Rocket Propulsion*, Macmillan (2010).

AE412 AEROSPACE VEHICLE DESIGN (3 – 0 – 0) 3 credits

Aircraft Design: introduction – weight estimation – airfoil and geometry selection – thrust to weight ratio and wing loading – initial sizing – propulsion – landing gear and subsystems – aerodynamics – stability, control, and handling qualities – flight mechanics and performance issues.

Space Vehicle Design: mission design – basic orbital mechanics – range safety – rocket propulsion options – attitude determination and control – configuration and structural design – thermal control – power systems – design for re-entry – vehicle integration and recovery – introduction to multi-disciplinary design optimization.

Textbooks:

1. Raymer, D. P., *Aircraft Design: A Conceptual Approach*, 4th ed., AIAA Edu. Series (2006).
2. Griffin, M. D. and French, J. R., *Space Vehicle Design*, 2nd ed., AIAA Edu. Series (2004).

References:

1. Anderson, J. D., *Aircraft Design*, McGraw-Hill (1999).
2. Corke, T. C., *Design of Aircraft*, Prentice Hall (2002).
3. Fielding, J. P., *Introduction to Aircraft Design*, Cambridge Univ. Press (1999).

E02	*ELECTIVE II*	(3 – 0 – 0) 3 credits

E03	*ELECTIVE III*	(3 – 0 – 0) 3 credits

E04	*ELECTIVE IV*	(3 – 0 – 0) 3 credits

E05	*INSTITUTE ELECTIVE*	(3 – 0 – 0) 3 credits

AE431	FLIGHT MECHANICS AND PROPULSION LAB	(0 – 0 – 3) 1 credit

- Flight Mechanics
  - Study of pull up - pull down manoeuvres and steady level turn
  - Study of RC helicopter
  - Simulation of model RC aircraft using flight 5.5
- Propulsion Engineering
  - Study and analysis of gas turbine cycle
  - Performance analysis of turbojet engine
  - Experiments on axial flow fan
  - Experimental impulse turbine module
  - Experimental reaction turbine module
  - Experiments on ramjet engine

AE451	SUMMER INTERNSHIP AND TRAINING	3 credits

AE452	COMPREHENSIVE VIVA-VOCE I	2 credits

SEMESTER VIII

AE453	COMPREHENSIVE VIVA-VOCE II	3 credits
AE454	PROJECT WORK	12 credits

ELECTIVES

AE461 ADVANCED AERODYNAMICS (3 – 0 – 0) 3 credits

Introduction to experimental aerodynamic facilities – classification of experimental facilities – continuous, blow-down and impulse facilities – wind tunnel instrumentation – special testing techniques.

Introduction to computational aerodynamics – various levels of approximations – grid generation – boundary conditions.

Introduction to hypersonic flows – analytical and computational methods – hypersonic boundary layer theory – aerodynamic heating – viscous-inviscid interactions.

Re-entry vehicle aerodynamics – earth and Martian atmosphere models – continuum and free molecular flows.

Introduction to aerothermodynamics – real and perfect gases – chemical equilibrium and non-equilibrium – solutions for stagnation point flow.

Introduction to kinetic theory of gases – introduction to turbulence – use of turbulent models for external flows.

Textbooks:

1. Anderson Jr, J. D., *Hypersonic and High-Temperature Gas Dynamics*, 2nd ed., AIAA Edu. Series (2006).
2. Barlow, J. B., Rae Jr, W. H., and Pope, A., *Low-Speed Wind Tunnel Testing*, 3rd ed., Wiley (1999).
3. Versteeg, H. K., Malalasekera, W., *An Introduction to Computational Fluid Dynamics: The Finite Volume Method*, 2nd ed., Prentice Hall (2007).

References:

1. Pope, A. and Goin K. L., *High-Speed Wind Tunnel Testing*, Krieger Pub. Co. (1978).
2. Goethert, B. H., *Transonic Wind Tunnel Testing*, Dover (2007).
3. Hirschel, E. H. and Weiland, C., *Selected Aerothermodynamic Design Problems of Hypersonic Flight Vehicles*, AIAA/Springer (2009).
4. Toro, E. F., *Riemann Solvers and Numerical Methods for Fluid Dynamics: A Practical Introduction*, 2nd ed., Springer-Verlag (1999).

AE462 ADVANCED AEROSPACE STRUCTURES (3 – 0 – 0) 3 credits

Description of essential features of aircraft, rocket and spacecraft structures – type of loads on flight structures – bending, shear and torsion of open and closed thin-walled beams – monocoque, stiffened plate, isogrid and sandwich constructions – idealization and stress analysis of typical aerospace structural components – pressurized structures – stress discontinuities – effects of cut-outs – effects of boundary conditions in open and closed section beams – structural fatigue.

Textbook:

- Megson, T. H. G., *Aircraft Structures for Engineering Students*, 4th ed., Butterworth-Heinemann (2007).

References:

1. Timoshenko, S. P. and Goodier, J. N., *Theory of Elasticity*, 3rd ed., McGraw-Hill (1970).
2. Timoshenko, S. P. and Woinowsky-Krieger, S., *Theory of Plates and Shells*, 2nd ed., McGraw-Hill (1964).
3. Bruhn, E. F., *Analysis and Design of Flight Vehicle Structures*, 2nd ed., Jacobs Publishing Inc. (1973).

AE463 ADVANCED FLUID MECHANICS (3 – 0 – 0) 3 credits

Fluid kinematics – physical conservation laws – review of integral and differential formulations – Navier–Stokes and energy equations – solution of Navier–Stokes equations; steady and unsteady flows – waves in fluids (potential flow formulation) – boundary layer theory; Blasius solution, Falkner–Skan solutions, momentum integral approach – introduction to turbulent flows.

References:

1. White, F. M., *Viscous Fluid Flow*, 3rd ed., McGraw-Hill (2006).
2. Panton, R. L., *Incompressible Flow*, 3rd ed., John Wiley (2005).
3. Kundu, P. K., Cohen, I. M., and Dowling, D. R., *Fluid Mechanics*, 5th ed., Academic Press (2012).
4. Leal, L. G., *Advanced Transport Phenomena*, Cambridge Univ. Press (2007).
5. Schlichting, H. and Gersten, K., *Boundary Layer Theory*, 8th ed., McGraw-Hill (2001).

AE464 ADVANCED HEAT TRANSFER (3 – 0 – 0) 3 credits

Radiation Heat Transfer: fundamentals – view factors – network method and enclosure analysis for gray – diffuse enclosures containing transparent media – engineering treatment of gas radiation.

Two Phase Flow: fundamentals – flow patterns – basic equations for homogeneous flow and the separated-flow model.

Boiling Heat Transfer: pool boiling – forced convective – cross flow – multicomponent boiling – correlations for boiling coefficient – critical heat flux.

Condensation: modes of condensation – film-wise condensation on vertical surfaces – horizontal tube systems – condensation in multicomponent systems.

Enhancement of Heat Transfer: active, passive, and compound techniques.

Textbooks:

1. Incroprera, F. P. and Dewitt, D. P., *Heat and Mass Transfer*, 5th ed., Wiley (2002).
2. Hewitt, G. F., Shires, G. L., and Bott, T. R., *Process Heat Transfer*, CRC Press (1994).

References:

1. Çengel, Y. A., *Heat and Mass Transfer*, 3rd ed., Tata McGraw-Hill (2007).
2. Das, S. K., *Process Heat Transfer*, Narosa (2006).
3. Sparrow, E. M. and Cess, R. D., *Radiation Heat Transfer*, CRC Press (1978).

AE466 STRUCTURAL DYNAMICS AND AEROELASTICITY (3 – 0 – 0) 3 credits

Fundamental aspects of structural dynamics – free vibration and modal representation of flexible structures – application to beam extension, shear, bending and torsion dynamics – static aeroelasticity – wind tunnel models – divergence and aileron reversal – Lifting surfaces: torsional divergence and load redistribution, aeroelastic tailoring – aeroelastic flutter – stability characteristics – Flutter analysis: wind tunnel models – flexible wings.

Textbook:

- Hodges, H., *Introduction to Structural Dynamics and Aeroelasticity*, Cambridge Univ. Press (2002).

AE467 ANALYSIS AND DESIGN OF COMPOSITE STRUCTURES (3 – 0 – 0) 3 credits

Introduction – classification and applications of composites – fiber-reinforced composites – micro and macro-mechanical analysis – analysis of simple laminated composite structural elements – failure and fracture of composite lamina – bending and vibration of composite and sandwich structural elements – design of aerospace composite and sandwich structures.

Textbook:

- Jones, R. M., *Mechanics of Composite Materials*, 2nd ed., Taylor & Francis (1999).

References:

1. Gibson, R. F., *Principles of Composite Materials Mechanics*, 2nd ed., McGraw-Hill (1994).
2. Daniel, I. M. and Ishai, O., *Engineering Mechanics of Composite Materials*, 2nd ed., Oxford Univ. Press (2005).
3. Hong, T. H. and Tsai, S. W., *Introduction to Composite Materials*, Technomic Pub. Co. (1980).
4. Vasiliev, V. V. and Morozov, E. V., *Advanced Mechanics of Composite Materials*, 3rd ed., Elsevier (2007).

AE468 COMPUTATIONAL FLUID DYNAMICS (3 – 0 – 0) 3 credits

Mathematical models for fluid dynamics – classification of partial differential equations – discretization methods – finite difference formulation – numerical solution of elliptic equations – linear system of algebraic equations – numerical solution of parabolic equations – stability analysis – numerical solution of hyperbolic equations – Burgers equation – incompressible Navier-Stokes equations and their solution algorithms – finite volume method.

Textbook:

- Hirsch, C., *Numerical Computation of Internal and External Flows: The Fundamentals of Computational Fluid Dynamics*, Vol. I, 2nd ed., Butterworth-Heinemann (2007).

References:

1. Tannehill, J. C., Anderson, D. A., and Pletcher, R. H., *Computational Fluid Mechanics and Heat Transfer*, 2nd ed., Taylor & Francis (1997).
2. Hoffmann, K. A. and Chiang, S. T., *Computational Fluid Dynamics for Engineers*, 4th ed., Engineering Education Systems (2000).
3. Anderson, J. D., *Computational Fluid Dynamics: The Basics with Applications*, McGraw-Hill (1995).
4. Patankar, S. V., *Numerical Heat Transfer and Fluid Flow*, Hemisphere (1980).
5. Ferziger, J. H. and Perić, M., *Computational Methods for Fluid Dynamics*, 3rd ed., Springer (2002).

AE469 COMPUTER INTEGRATED MANUFACTURING (3 – 0 – 0) 3 credits

Manufacturing Systems: computer integrated manufacturing – computer aided design (CAD) and engineering (CAE) – computer aided manufacturing (CAM) and concurrent engineering.

NC, CNC and DNC; CNC Machines: general concepts, design features, drives and controls, programming – adaptive control – machining centres.

Shop Floor Automation: automated material handling – assembly and inspection – computer aided process planning (CAPP) – computer integrated production management system – group technology and cellular manufacturing – flexible manufacturing system – automatic storage/retrieval systems (AS/RS) – Just In Time (JIT) – lean manufacturing.

Textbook:

- Groover, M. P., *Automation, Production Systems and Computer Integrated Manufacturing*, 3rd ed., Prentice Hall of India (2007).

References:

1. Kant Vajpayee, S., *Principles of Computer Integrated Manufacturing*, Prentice Hall of India (1995).
2. Rehg, J. A. and Kraebber, H. W., *Computer Integrated Manufacturing*, 3rd ed., Pearson Prentice Hall (2004).
3. Venkateswaran, N. and Alavudeen, A., *Computer Integrated Manufacturing*, Prentice Hall of India (2008).
4. Groover, M. P. and Zimmers, E. W., *CAD/CAM: Computer-Aided Design and Manufacturing*, Prentice Hall of India (1984).

AE470 DESIGN 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).

AE471 CONVECTION HEAT TRANSFER (3 – 0 – 0) 3 credits

Introduction transport properties for viscous, conducting fluids – kinematic properties – fundamental conservation equations; Navier-Stokes equations and energy equation – dimensionless parameters – solution of Newtonian viscous flows – laminar shear layers momentum, thermal – laminar heat transfer in ducts – incompressible turbulent mean flows – free convection flows – mass transfer coupled flows convection with phase change – convection in porous media.

Textbooks:

1. Bejan, A., *Convection Heat Transfer*, Wiley, 3rd ed., Wiley (2004).
2. Burmeister, L. C., *Convective Heat Transfer*, 2nd ed., Wiley (1993).

AE472 EXPERIMENTAL AERODYNAMICS (3 – 0 – 0) 3 credits

Introduction to aerodynamic test facilities in various Mach number regimes: low speed, transonic, supersonic, hypersonic, and high enthalpy – design of subsonic, transonic, and supersonic wind tunnels – wind tunnel calibration – low speed flow visualisation techniques – dynamic stability derivatives – design of hypersonic wind tunnels – design of shock tube / shock tunnels – calibration of various wind tunnels – Flow visualisation techniques: Schlieren, shadowgraph, interferometry – introduction to laser diagnostic techniques – RTD, thermocouples, thermography, etc. – force measurement techniques in shock tunnel – introduction to wind tunnel instrumentation – Measurements techniques in wind tunnels: forces and moments, pressure, velocity, temperature, aeroacoustic measurements – error analysis – Instrumentation / data acquisition: steady and unsteady, shock tunnel data acquisition – virtual instrumentation – PLCs – measurement of steady and unsteady pressure, velocity, temperature, turbulence intensity, hot-wire, skin friction, forces and moments – Model design and fabrication: RP, FRP, metal, actuators – calibration of force, pressure and acoustic sensors.

References:

1. Barlow, J. B., Rae Jr, W. H., and Pope, A., *Low-Speed Wind Tunnel Testing*, 3rd ed., Wiley (1999).
2. Pope, A. and Goin K., *High-Speed Wind Tunnel Testing*, Krieger Pub. Co. (1972).
3. Goethert, B. H., *Transonic Wind Tunnel Testing*, Dover Publications (2007).
4. Pavian H. C., *Experimental Aerodynamics*, Pitman Publishing (1940).
5. Mueller, T. J., Allen, C. S., Blake, W. K., Dougherty, R. P., Lynch, D., Soderman, P. T., and Underbrink, J. R., *Aeroacoustic Measurements*, Springer (2010).
6. Langley, S. P., *Experiments in Aerodynamics*, Nabu Press (2010).

AE473 FINITE ELEMENT METHOD (3 – 0 – 0) 3 credits

Introduction – finite element formulation from differential equation – finite element formulation based on stationarity of a functional – one-dimensional finite element analysis; shape functions, types of elements, applications – two-dimensional finite element analysis – numerical integration – applications to structural mechanics and fluid flow.

References:

1. Seshu, P., *Textbook of Finite Element Analysis*, Prentice Hall of India (2009).
2. Segerlind, L. J., *Applied Finite Element Analysis*, 2nd ed., John Wiley (1984).
3. Chandrupatla, T. R. and Belegundu, A. D., *Introduction to Finite Elements in Engineering*, 2nd ed., Prentice Hall of India (2000).
4. Henwood, D. and Bonet, J., *Finite Elements: A Gentle Introduction*, Macmillan (1996).
5. Reddy, J. N., *Introduction to the Finite Element Method*, 3rd ed., McGraw-Hill (2006).

AE474 FRACTURE MECHANICS (3 – 0 – 0) 3 credits

Introduction and history of fracture mechanics – linear elastic fracture mechanics; energy release rate, stress intensity factor (SIF), relation between SIF and energy release rate, anelastic deformation at the crack tip – crack growth and fracture mechanisms – elastic-plastic analysis through J-integral – finite element analysis of cracks – fracture toughness testing – fatigue failure.

Textbook:

- Prashant Kumar, *Elements of Fracture Mechanics*, Tata McGraw-Hill (2009).

References:

1. Broek, D., *Elementary Engineering Fracture Mechanics*, 4th ed., Kluwer Academic (1986).
2. Anderson, T. L., *Fracture Mechanics: Fundamentals and Applications*, 3rd ed., CRC Press (2004).

AE475 ENGINEERING VIBRATION (3 – 0 – 0) 3 credits

Introduction to vibration – single degree of freedom systems: free, undamped, damped, and forced vibrations – two-degree of freedom systems: principal modes of vibration, undamped vibration, forced vibration, forced damped vibrations – vibration isolation – multi-degree Freedom systems: eigenvalue problem – orthogonality of mode shapes, modal analysis for free, damped, and forced vibration systems – approximate methods for fundamental frequency – introduction to transient vibrations and non-linear vibrations.

Textbook:

- Rao, S. S., *Mechanical Vibrations*, 4th ed., Pearson Education (2004).

References:

1. Thomson, W. T. and Daleh, M. D., *Theory of Vibration with Applications*, 5th ed., Prentice Hall (1997).
2. Rao, J. S. and Gupta, K., *Introductory Course on Theory and Practice of Mechanical Vibrations*, 2nd ed., New Age International (1999).
3. Meirovitch, L., *Elements of Vibration Analysis*, 2nd ed., McGraw-Hill (1986).
4. Seto W. W., *Schaum's Outline of Theory and Problems of Mechanical Vibrations*, McGraw-Hill (1964).

AE476 INDUSTRIAL ENGINEERING (3 – 0 – 0) 3 credits

Introduction, production planning and control – product design – value analysis and value engineering – plant location and layout – equipment selection – maintenance planning – job, batch, and flow production methods – group technology – work study – time and motion study – work/job evaluation – inventory control – manufacturing planning – total quality management – Taguchi's quality engineering – network models.

Textbooks:

1. Narasimhan, S. L., McLeavey D. W., and Billington, P. J., *Production, Planning and Inventory Control*, Prentice Hall (1977).
2. Riggs, J. L., *Production Systems: Planning, Analysis and Control*, 3rd ed., Wiley (1981).

References:

1. Muhlemann, A., Oakland, J. O., and Lockyer, K., *Productions and Operations Management*, Macmillan (1992).
2. Taha, H. A., *Operations Research: An Introduction*, Prentice Hall of India (1997).
3. Sharma, J. K., *Operations Research*, Macmillan (1997).

AE477 FUNDAMENTALS OF COMBUSTION (3 – 0 – 0) 3 credits

Combustion and thermochemistry – chemical kinetics and mechanisms – reacting flows-premixed flames – detonation and explosion – diffusion flames.

Textbook:

- Turns, S. R., *An Introduction to Combustion*, 2nd ed., McGraw-Hill (2000).

References:

1. Glassman, I. and Yetter, R. A., *Combustion*, 4th ed., Elsevier (2008).
2. Kuo, K. K., *Principles of Combustion*, 2nd ed., John Wiley (2005).
3. Warnatz, J., Maas, U., and Dibble, R. W., *Combustion* 4th ed., Springer (2006).
4. Law C. K., *Combustion Physics*, Cambridge Univ. Press (2006).

AE478 SUPPLY CHAIN MANAGEMENT (3 – 0 – 0) 3 credits

Introduction and a strategic view of supply chains – evolution of supply chain management (SCM) – decision phases in a supply chain – enablers of supply chain performance – supply chain strategy and performance measures – achieving strategic fit – network design in the supply chain – supply chain drivers and obstacles – operations decisions in supply chains – forecasting, aggregate planning – inventory control in supply chain – sourcing decisions in supply chain – supplier selection – transportation in supply chain – routing and scheduling using savings matrix method – coordination in supply chain – bullwhip effect – enabling supply chain management through information technology.

Textbook:

- Chopra, S. and Meindl, P., *Supply Chain Management: Strategy, Planning, and Operation*, Pearson Prentice Hall of India (2007).

References:

1. Levi, D. S., Kaminsky, P., Levi, E. S., and Shankar, R., *Designing and Managing the Supply Chain: Concepts, Strategies, and Case Studies*, Tata McGraw-Hill (2008).
2. Stadtler, H. and Kilger, C., *Supply Chain Management and Advanced Planning: Concepts, Models, Software and Case Studies*, 3rd ed., Springer-Verlag (2003).
3. Shapiro, J. F., *Modeling the Supply Chain*, Thomson Learning (2007).
4. Vollmann, T. E., Berry, W. L., Whybark, D. C., and Jacobs, F. R., *Manufacturing Planning and Control for Supply Chain Management*, Tata McGraw-Hill (2006).

AE479 INTRODUCTION TO OPTIMIZATION (3 – 0 – 0) 3 credits

Optimization in science and engineering – general and special classes of problems – characterization of unconstrained and constrained minima – Lagrange multipliers – KKT conditions – linear programming – simplex tableau – duality – one dimensional optimization – elimination and interpolation techniques – multidimensional unconstrained minimization – steepest descent – Newton's and quasi-Newton techniques – randomized searches – genetic algorithm and simulated annealing – introduction to constrained minimization – large scale problems – multi-disciplinary optimization – applications in design, analysis, and control.

Textbook:

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

References:

1. Rao, S. S., *Engineering Optimization: Theory and Practices*, 4th ed., John Wiley (2009).

AE480 NONTRADITIONAL MACHINING (3 – 0 – 0) 3 credits

Nontraditional machining – thermal, chemical, and abrasives techniques; need, principle, process mechanics and variables, equipments, performance characteristics – application and recent trends of electrical discharge machining (EDM), wire EDM, wire EDG, electro-chemical machining (ECM), ECG, ultrasonic, laser beam, electron beam, abrasive and water jet machining, and hybrid processes – nontraditional micromachining.

Textbooks:

1. Jain, V. K., *Advanced Machining Processes*, Allied Pub. (2002).
2. Mishra, P. K., *Nonconventional Machining*, Narosa (2006).

References:

1. Sharma, P. C., *A Textbook of Production Engineering*, S. Chand & Co. (2005).
2. Benedict, G. F., *Non-Traditional Machining Processes*, Marcel Dekker (1987).
3. Pandey, P. C. and Shan, H. S., *Modern Machining Process*, Tata McGraw-Hill (2004).

AE481 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*, 2nd ed., John Wiley (2012).
2. Taha, H. A., *Operations Research: An introduction*, 9th ed., Prentice Hall of India (2010).
3. Winston, W. L., *Operations Research: Applications and Algorithms*, 4th ed., Cengage Learning (2010).
4. Rao, S. S., *Engineering Optimization: Theory and Practices*, 4th ed., John Wiley (2009).

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

AE482 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).

AE483 INTRODUCTION TO ROBOTICS (3 – 0 – 0) 3 credits

Overview of robotics – different types of robots – manipulators and mobile robots – mechanisms used in robots – serial and parallel chains – degrees of freedom – means of mobility, rovers.

Rigid body displacements – homogenous transformation – mechanism parameters – Denavit–Hartenberg notation – forward and inverse kinematic problems – velocity and static analysis.

Higher level control – motion planning, obstacle avoidance – road map and potential field methods – higher level sensors – vision, laser and ultrasonic range finders – localization and mapping.

References:

1. Ghosal, A., *Robotics: Fundamental Concepts and Analysis*, Oxford Univ. Press (2006).
2. 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).
3. Craig, J. J., *Introduction to Robotics: Mechanics and Control*, 2nd ed., Pearson Education (2001).

AE484 SPACE MISSION DESIGN AND OPTIMIZATION (3 – 0 – 0) 3 credits

Launch vehicle ascent trajectory design – reentry trajectory design – low thrust trajectory design – satellite constellation design – rendezvous mission design – ballistic lunar and interplanetary trajectory design – basics of optimal control theory – mission design elements for various missions – space flight trajectory optimization – direct and indirect optimization techniques – restricted 3-body problem – Lagrangian points – mission design to Lagrangian point.

Textbooks:

1. Osborne, G. F. and Ball, K. J., *Space Vehicle Dynamics*, Oxford Univ. Press (1967).
2. Hale, F. J., *Introduction to Space Flight*, Prentice Hall (1994).
3. Naidu, D. S., *Optimal Control Systems*, CRC Press (2003).

References:

1. Chobotov, V., *Orbital Mechanics*, AIAA Edu. Series (2002).
2. Griffin, M. D. and French, J. R., *Space Vehicle Design*, 2nd ed., AIAA (2004).
3. Kirk, D. E., *Optimal Control Theory: An Introduction*, Dover (1998).
4. Bulirsch, R., Miele, A., Stoer, J., and Well, K. H. (Ed.), *Optimal Control: Calculus of Variations, Optimal Control Theory and Numerical Methods*, Birkhauser Verlag (1993).

AE486 REFRIGERATION AND CRYOGENICS (3 – 0 – 0) 3 credits

Refrigeration: introduction – analysis of VCR cycles – multistage, multi-evaporator, cascade systems – properties and selection of pure and mixed refrigerants – properties of binary mixtures – analysis of vapor absorption cycles – aqua ammonia and LiBr water cycles – air cycle refrigeration, vortex tube, thermoelectric refrigeration.

Cryogenic Engineering: historical background and applications – gas liquefaction systems – gas separation and gas purification systems – cryogenic refrigeration systems – storage and handling of cryogens – cryogenic insulations – liquefied natural – gas-properties of materials of low temperatures – material of construction and techniques of fabrication – instrumentation – ultra-low temperature techniques – application.

Textbooks:

1. Stoecker, W. F. and Jones, J. W., *Refrigeration & Air Conditioning*, Tata McGraw-Hill (1986).
2. Barron, R. F., *Cryogenic Systems*, 2nd ed., Oxford Univ. Press (1985).

References:

1. Gosney W. B, *Principles of Refrigeration*, Cambridge Univ. Press (1982).
2. Weisend, J. G., *The Handbook of Cryogenic Engineering*, Taylor & Francis (1998).

AE487 TURBOMACHINES (3 – 0 – 0) 3 credits

Classification – specific work – representation of specific work in T-s and h-s diagrams – Internal and external losses – Euler's equation of turbomachinery – ideal and actual velocity triangles – slip and its estimation – impulse and reaction type machines – degree of reaction – effect of outlet blade angle on blade shape – model laws, specific speed and shape number – special features of steam and gas turbines – performance characteristics of turbomachines – cavitation, surge and stall – thin aerofoil theory – cascade mechanics.

Textbook:

- Dixon, S. L. and Hall, C. A., *Fluid Mechanics and Thermodynamics of Turbomachinery*, 6^{th} ed., Butterworth-Heinemann (2010).

References:

1. Baskharone, E. A., *Principles of Turbomachinery and in Air-Breathing Engines*, Cambridge Univ. Press (2006).
2. Wright, T., *Fluid Machinery: Performance, Analysis, and Design*, CRC Press (1999).

AE488 ADVANCED MANUFACTURING AND AUTOMATION (3 – 0 – 0) 3 credits

Precision Engineering: concepts, materials, processes – high speed machining; CNC machine tools and machining centres, adaptive systems, multi axis CNC programming – micro/nano scale manufacturing – recent development in nontraditional machining.

Automation: introduction to automated manufacturing, basic concepts, automated work piece handling, orientation, positioning – flexible automation – assembly automation, product design for automation – automated inspection – sensors and actuators for automation – PLC programming and applications in automation.

Textbooks:

1. Groover, M. P., *Automation, Production Systems, and Computer-Integrated Manufacturing*, 3^{rd} ed., Prentice Hall (2007).
2. Boothroyd, G., *Assembly Automation and Product Design*, 2^{nd} ed., CRC Press (2005).

AE489 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.

Textbooks:

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).

References:

1. Cantor, B., Assender, H., and Grant, P. (Ed.), *Aerospace Materials*, CRC Press (2001).
2. *ASM Speciality Handbook: Heat Resistant Materials*, ASM International (1997).
3. Campbell, F. C., *Manufacturing Technology for Aerospace Structural Materials*, Elsevier (2006).
4. Kainer, K. U. (Ed.), *Metal Matrix Composites*, Wiley-VCH (2006).

AE490 HEAT TRANSFER IN SPACE APPLICATIONS (3 – 0 – 0) 3 credits

Space Craft Thermal Environments: launch and ascent environments – environment of earth orbit – environments of interplanetary missions.

Thermal Control Techniques: passive thermal control techniques: thermal coating materials, thermal insulation, heat sinks, phase change materials – Active thermal control techniques: electrical heaters, thermal louvers, HPR fluid systems, heat pipes, spaceborne cooling systems.

Insulation-Blanket Design: materials-attachment – high temperature blankets – insulation for in-atmosphere applications.

Phase change materials – when to use a PCM-PCM design.

Heat Pipes-Types-Analysis-Testing: heat pipe applications and performances.

Thermal Contact Resistance and Its Calculation: parameters influencing thermal joint resistance-effect of oxidation and interstitial effects.

Ablative Heat Transfer: physical process and calculation of ablation rates – hypersonic ablation of graphite – heat transfer at high velocities – heat transfer in rarefied gases-transpiration and film cooling.

Textbook:

- Gilmore, D. G., *Spacecraft Thermal Control Handbook, Volume I: Fundamental Technologies*, 2nd ed., The Aerospace Press, American Institute of Aeronautics and Astronautics (2002).

References:

1. Fortescue, P., Swinerd, G., and Stark, J. (Ed.), *Spacecraft Systems Engineering*, 4th ed., John Wiley & Sons (2011).
2. Mayer, R. X., *Elements of Space Technology for Aerospace Engineers*, Academic Press (1999).
3. NASA SP 8105.

AE491 STRUCTURAL DYNAMICS (3 – 0 – 0) 3 credits

Review of vibration of SDOF systems – response to transient loading – response to general dynamic loading – multi degree of freedom systems – vibration of continuous systems; strings, rods, shafts, beams, and plates – natural modes of vibration; exact solutions and approximate methods – introduction to random vibrations.

Textbook:

- Meirovitch, L., *Elements of Vibration Analysis*, 2nd ed., Tata McGraw-Hill (2006).

References:

1. Meirovitch, L., *Analytical Methods in Vibrations*, Macmillan (1967).
2. Clough, R. W., and Penzien, J., *Dynamics of Structures*, 2nd ed., McGraw-Hill (1993).
3. Craig, R. R., *Structural Dynamics: An Introduction to Computer Methods*, John Wiley (1982).
4. Thomson, W. T. and Daleh, M. D., *Theory of Vibration with Applications*, 5th ed., Prentice Hall (1997).

AE493 TWO-PHASE FLOW AND HEAT TRANSFER (3 – 0 – 0) 3 credits

Review of Single-Phase Flows: one-dimensional conservation equations – introduction to two-phase flows – flow regimes.

Flow Models for Two-Phase Flows: one-dimensional homogeneous flow model – separated flow model – drift flux model – simplified treatment of bubbly, slug, and annular flows – flow regime maps – transition criterion – pressure drop correlations and void fraction correlation – phenomenological description of flooding – critical two-phase flows – prediction models.

Liquid-Vapour Phase Change Phenomenon: pool boiling – wetting phenomenon – bubble dynamics – nucleation concepts – convective boiling – heat transfer in partially and fully developed sub-cooled boiling – heat transfer in saturated boiling.

Critical Heat Flux: prediction methodologies – instabilities in boiling channel – methodologies for prediction.

Condensation Fundamentals: film condensation theory – dropwise condensation theory – introductory aspects of flow instabilities in condensation.

Flow Modeling: flow modeling aspects in natural and forced circulation heat removal in boiling systems – handling cryogenic fluid flow systems – modeling of pulsating heat pipe for electronic cooling.

References:

1. Kleinstreuer, C., *Two-Phase Flow: Theory and Application*, Taylor & Francis (2003).
2. Tong, L. S. and Tang, Y. S., *Boiling Heat Transfer and Two-Phase Flow*, 2nd ed., Taylor & Francis (1997).
3. Collier, J. G. and Thome, J. R., *Convective Boiling and Condensation*, 3rd ed., Oxford Univ. Press (2002).
4. Carey, V. P., *Liquid-Vapour Phase-Change Phenomenon: An Introduction to the Thermophysics of Vaporization and Condensation Process in Heat Transfer Equipment*, 2nd ed., Taylor & Francis (2007).
5. Wallis, G. B., *One-Dimensional Two-Phase Flow*, McGraw-Hill (1969).
6. Bailey, C. A. (Ed.), *Advanced Cryogenics*, Plenum Press (1971).

AE494 TURBULENCE IN FLUID FLOWS (3 – 0 – 0) 3 credits

Introduction to turbulence – equations of fluid motion – statistical description of turbulent flows – mean-flow equations – space and time scales of turbulent motion – jets, wakes, and boundary layers – coherent structures – spectral dynamics – homogeneous and isotropic turbulence – two-dimensional turbulence – coherent structures – vorticity dynamics – intermittency – modeling of turbulent flows.

References:

1. Tennekes H. and Lumley J. L., *A First Course in Turbulence*, The MIT Press (1972).
2. Frisch U., *Turbulence*, Cambridge Univ. Press (1996).
3. Davidson P. A., *Turbulence: An Introduction to Scientist and Engineers*, Oxford Univ. Press (2004).
4. Pope, S. B., *Turbulent Flows*, Cambridge Univ. Press (2000).
5. Mathieu J. and Scott, J., *An Introduction to Turbulent Flow*, Cambridge Univ. Press (2000).

AE495 HIGH TEMPERATURE GAS DYNAMICS (3 – 0 – 0) 3 credits

General features and applications of high temperature flows – equilibrium kinetic theory: Maxwellian distribution, collision rates and mean free path – chemical thermodynamics – mixture of perfect gases, law of mass action – statistical mechanics: enumeration of micro-states, energy distribution, contribution of internal structure – equilibrium flow: ideal dissociating gas, equilibrium shock wave relations, nozzle flows – vibrational and chemical rate processes – flows with vibrational and chemical non-equilibrium.

References:

1. Vincenti, W. G. and Kruger, C. H., *Introduction to Physical Gas Dynamics*, Krieger Pub. (1975).
2. Anderson, J. D., *Hypersonic and High-Temperature Gas Dynamics*, 2nd ed., AIAA (2006).
3. Clarke, J. F. and McChesney, M., *The Dynamics of Real Gases*, Butterworths (1964).
4. Brun, R., *Introduction to Reactive Gas Dynamics*, Oxford Univ. Press (2009).

AE496 MULTIDISCIPLINARY DESIGN OPTIMIZATION (3 – 0 – 0) 3 credits

Multidisciplinary Design Optimization (MDO) – need and importance, coupled systems – analyser vs. evaluator, single vs. bi-level optimisation, nested vs. simultaneous analysis/design MDO architectures – concurrent subspace, collaborative optimisation and BLISS – sensitivity analysis, AD (forward and reverse mode), complex variable, and hyperdual numbers – gradient and Hessian – uncertainty quantification – moment methods – PDF and CDF – uncertainty propagation – Monte Carlo methods – surrogate modelling – design of experiments – robust, reliability based and multi-point optimisation formulations.

References:

1. Keane, A. J. and Nair, P. B., *Computational Approaches for Aerospace Design: The Pursuit of Excellence*, Wiley (2005).
2. Khuri, A. I. and Cornell, J. A., *Response Surfaces: Design and Analyses*, 2nd ed., Marcel Dekker (1996).
3. Montgomery, D. C., *Design and Analysis of Experiments*, 8th ed., John Wiley (2012).
4. Griewank, A. and Walther, A., *Evaluating Derivatives: Principles and Techniques of Algorithmic Differentiation*, 2nd ed., SIAM (2008).

AE497 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).

AE498 COMPUTATIONAL METHODS FOR COMPRESSIBLE FLOW (3 – 0 – 0) 3 credits

Basic equations – hierarchy of mathematical models – mathematical nature of flow equations and boundary conditions – finite difference and finite volume methods – analysis of schemes: numerical errors, stability, numerical dissipation – grid generation – wave equation – numerical solution of compressible Euler equation: discontinuities and entropy, mathematical properties of Euler equation – reconstruction-evolution – upwind methods – boundary conditions – numerical solution of compressible Navier-Stokes equations – turbulence modeling: RANS, LES, DNS – higher-order methods – uncertainty in CFD: validation and verification.

References:

1. Hirsch C., *Numerical Computation of Internal and External Flows*, Vol. I & II, Wiley (1998).
2. Laney, C. B., *Computational Gasdynamics*, Cambridge Univ. Press (1998).
3. LeVeque, R. J., *Numerical Methods for Conservation Laws*, 2nd ed., Birkhauser (2005).
4. Hoffmann, K. A. and Chiang, S. T., *Computational Fluid Dynamics for Engineers*, Vol. I, II & III, Engineering Education Systems (2000).
5. Toro, E. F., *Riemann Solvers and Numerical Methods for Fluid Dynamics: A Practical Introduction*, 3rd ed., Springer (2009).
6. Blazek, J., *Computational Fluid Dynamics: Principles and Applications*, 2nd ed., Elsevier (2006).
7. Roache, P. J., *Fundamentals of Verification and Validation* Hermosa Publishers (2009).

AE499 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).