Indian Institute of Space Science and Technology

Thiruvananthapuram

B.Tech. Aerospace Engineering
Curriculum & Syllabus

(Effective from 2019 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
CHxxx	Environmental Science and Engineering	2	-	-	2
AV111	Basic Electrical Engineering	3	-	-	3
HS111	Communication Skills	2	-	3	3
PH131	Physics Lab	-	-	3	1
AE131	Basic Engineering Lab	-	-	3	1
	Total	15	3	9	21

SEMESTER II

CODE	TITLE	L	T	P	C
MA121	Vector Calculus and Ordinary 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 & Electronics Engineering Lab	-	-	3	1
	Total	14	2	12	20

SEMESTER III

CODE	TITLE	L	T	P	C
MA211	Linear Algebra, Complex Analysis, and Fourier Series	3	-	-	3
AE211	Engineering Thermodynamics	3	-	-	3
AE212	Mechanics of Solids	3	-	-	3
AE213	Fluid Mechanics	3	-	-	3
AE214	Materials Processing Techniques	3	-	-	3
AE215	Introduction to Machine Elements and Drawing	0	-	3	1
HS211	Introduction to Economics	2	-	-	2
AE231	Strength of Materials Lab	-	-	3	1
	Total	17	0	6	19

SEMESTER IV

CODE	TITLE	L	T	P	C
MA221	Integral Transforms, PDE, and Calculus of Variations	3	-	-	3
AE221	Aerodynamics	3	-	-	3
AE222	Heat Transfer	3	-	-	3
AE223	Applied Dynamics and Vibration	3	-	-	3
AE224	Machining Science and Technology	3	-	-	3
HS221	Introduction to Social Science and Ethics	2	-	-	2
AE241	Thermal and Fluid Lab	-	-	3	1
AE242	Metrology and Computer Aided Inspection	1	-	3	2
	Total	18	0	6	20

SEMESTER V

CODE	TITLE	L	T	P	C
MA311	Probability, Statistics, and Numerical Methods	3	-	-	3
AE311	Compressible Flow	3	-	-	3
AE312	Atmospheric Flight Mechanics	3	-	-	3
AE313	Spaceflight Mechanics	3	-	-	3
AE314	Theory of Elasticity	3	-	-	3
AV315	Automatic Control	2	1	-	3
AE331	Aerodynamics Lab	1	-	3	2
AE332	Manufacturing Processes Lab	-	-	3	1
AE342	Modeling and Analysis Lab	1	-	3	2
	Total	18	1	6	22

SEMESTER VI

CODE	TITLE	L	T	P	C
AE321	Air-Breathing Propulsion	3	-	-	3
AE322	Aerospace Structures	3	-	-	3
HS321	Principles of Management Systems	3	-	-	3
E01	*Elective I*	3	-	-	3
E02	*Elective II*	3	-	-	3
E03	*Elective III*	3	-	-	3
AE341	Aerospace Structures Lab	-	-	3	1
AE332	Manufacturing Processes Lab	-	-	3	1
	Total	19	0	6	20

SEMESTER VII

CODE	TITLE	L	T	P	C
AE411	Rocket Propulsion	3	-	-	3
AE412	Aerospace Vehicle Design	2	-	3	3
AE4xx	Optimization Techniques in Engineering	3	-	-	3
E03	*Elective III*	3	-	-	3
E04	*Elective IV*	3	-	-	3
E05	*Institute Elective*	2/3	-	-	2/3
AE431	Flight Mechanics and Propulsion Lab	-	-	3	1
AV435	Instrumentation and Control Systems Lab	1	-	3	2
AE451	Summer Internship and Training	-	-	-	3
	Total	18/17	0	9	23/24

SEMESTER VIII

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

SEMESTER–WISE CREDITS

Semester	I	II	III	IV	V	VI	VII	VIII	Total
Credits	21	20	19	20	21	21	23/24	15	160/161

LIST OF ELECTIVES

CODE	TITLE
AE457	Flight Dynamics and Control
AE458	Structural Acoustics and Noise Control
AE459	Machine Design
AE460	Aeroacoustics
AE461	Applied 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	Solar Thermal Energy
AE480	Boundary Layer Theory
AE481	Operations Research
AE482	High Temperature Gas Dynamics
AE483	Introduction to Robotics

AE484	Space Mission Design and Optimization
AE485	Molecular Dynamics and Materials Failure
AE486	Refrigeration and Cryogenics
AE487	Turbomachines
AE488	Precision Engineering 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	Introduction to Flow Instability
AE496	Multidisciplinary Design Optimization
AE497	Energy Methods in Engineering
AE498	Computational Methods for Compressible Flow
AE499	Elastic Wave Propagation in Solids
New	Theory of Plasticity & Metal forming
New	Human Behaviour in Organizations
New	Introduction to Space Laws
New	Numerical Methods for Scientific Computing

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., Wiley (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.

Textbook:

- Atkins, P. and de Paula, J., *Physical Chemistry*, 9th ed., Oxford Univ. Press (2010).

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).

CH411 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*, PHI Learning (2002).

References:

1. Baird, C. and Cann, M., *Environmental Chemistry*, 3rd ed., W. H. Freeman and Company (2005).
2. *Manual on Sewerage and Sewage Development*, CPHEEO, Ministry of Urban Development, GOI (1993).
3. Hauser, B. A., *Practical Hydraulics Hand Book*, Lewis Pub. (1991).
4. Hammer, M. J., *Water and Wastewater Technology*, Regents/Prentice Hall (1991).
5. Sharma, J. P., *Comprehensive Environmental Studies*, Laxmi Pub. (2004).
6. Garg, S. K., *Environmental Engineering* (Vol. 1 & Vol. 2), Khanna Pub. (2004).
7. Kiely, G., *Environmental Engineering*, McGraw-Hill (1997).
8. Bharucha, E., *Textbook of Environmental Studies*, University Grants Commission (2004).
9. Vanloon, G. W. and Duffy, S. J., *Environmental Chemistry: A Global Perspective*, Oxford Univ. Press (2000).

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*, 11^{th} ed., Pearson Education (2012).
2. Del Toro, V., *Electrical Engineering Fundamentals*, 2^{nd} ed., Prentice Hall (1986).

References:

1. Mittle, V. N. and Mittal, A., *Basic Electrical Engineering*, 2^{nd} 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*, 4^{th} 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*, PHI Learning (2013).
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-Savart's 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

Introduction to general purpose hand tools and measuring instruments used in engineering workshop – Introduction to machine elements like gears, cams, bearings etc. – Assembly and disassembly practices: gear box, pump etc. – Machining practices on conventional machine tools: lathe, milling and drilling practices – Welding practice – Simple fitting and assembly exercises – Electrical wiring and soldering.

SEMESTER II

MA121 VECTOR CALCULUS AND ORDINARY 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.

Ordinary Differential Equations: first order 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*, 3rd ed., John Wiley (2004).
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, Fermat's 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*, 3rd ed., PHI Learning (2015).

References:

1. Billmeyer, F. W., *Textbook of Polymer Science*, 3rd ed., Wiley (1994).
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*, 10th ed., Pearson Education (2009).
2. Mano, M. M. and Ciletti, M. D., *Digital Design*, 4th ed., Pearson Education (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*, 50^{th} 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*, 5^{th} ed., New Age International (2011).
3. Varghese, P. I., *Engineering Graphics with AutoCAD*, 26^{th} ed., VIP Publishers (2012).
4. Luzadder, W. J. and Duff, J. M., *Fundamentals of Engineering Drawing*, 11^{th} ed., Pearson Education (2015).
5. Bethune, J. D., *Engineering Graphics with AutoCAD 2014*, Pearson Education (2014).

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, COMPLEX ANALYSIS, AND FOURIER SERIES (3 - 0 - 0) 3 credits

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

Complex Analysis: 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.

Fourier Series and Integrals: expansion of periodic functions with period 2π – Fourier series of even and odd functions – half-range series – Fourier series of functions with arbitrary period – conditions of convergence of Fourier series – Fourier integrals.

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. Brown, J. W. and Churchill, R. V., *Complex Variables and Applications*, 9th ed., McGraw-Hill (2013).
2. Greenberg, M. D., *Advanced Engineering Mathematics*, Pearson Education (2007).
3. 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

Fundamentals – energy and the first law of thermodynamics – energy balance for systems and cycles – properties of pure, simple compressible substance – tables of thermodynamic properties – generalized compressibility chart and ideal gas model – conservation of mass and energy for a control volume – second law of thermodynamics and definition of entropy change – isentropic efficiency – exergy, available and unavailable energy – concept of irreversibility and lost work – thermodynamic cycles – introduction to statistical thermodynamics.

Textbook:

- Çengel, Y. A. and Boles, M. A., *Thermodynamics: An Engineering Approach*, 8th ed., McGraw-Hill (2014).

References:

1. Moran, M. J., Shapiro, H. N., Boettner, D. D., and Bailey, M. B., *Principles of Engineering Thermodynamics (SI Version)*, 8th ed., Wiley (2015).
2. Spalding, D. B. and Cole, E. H., *Engineering Thermodynamics*, 3rd ed., Edward Arnold (1973).
3. Nag, P. K., *Engineering Thermodynamics*, 3rd ed., Tata McGraw-Hill (2005).
4. Jones, J. B. and Dugan, R. E., *Engineering Thermodynamics*, Prentice Hall (1996).
5. Borgnakke, C. and Sonntag, R. E., *Fundamentals of Thermodynamics*, 8th ed., Wiley (2013).
6. Balmer, R. T., *Modern Engineering Thermodynamics*, Academic Press (2011).

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

Statics of rigid bodies – concepts of stress, strain – torsion – axial force, shear, and bending moment – pure bending – shear stress in beams – transformation of stresses and strains – failure criteria – 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., Pearson Education (2015).

References:

1. Hibbeler, R. C., *Mechanics of Materials*, 9th ed., Prentice Hall (2013).
2. Beer, F. P., Johnston, E. R., and DeWolf, J. T., *Mechanics of Materials*, 7th ed., McGraw-Hill (2014).
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*, 8th ed., McGraw-Hill (2015).

References:

1. Fox, R. W., McDonald, A. T., and Pritchard, P. J., *Introduction to Fluid Mechanics (SI Version)*, 8th ed., John Wiley (2013).
2. Çengel, Y. A. and Cimbala, J. M., *Fluid Mechanics: Fundamental and Applications*, 3rd ed., McGraw-Hill (2014).
3. Munson, B. R., Okiishi, T. H., Huebsch, W. W., and Rothmayer, A. P., *Fundamentals of Fluid Mechanics*, 7th ed., John Wiley (2013).

AE214 MATERIALS PROCESSING TECHNIQUES (3 – 0 – 0) 3 credits

Theory of plastic deformation yield criteria steels and heat treatment processes - Metal forming- theory, processes and systems applications of casting and forming operations manufacturing of fasteners.

Metal casting- theory, processes and systems Joining techniques in engineering/aerospace applications fusion and solid state welding, processes and systems Defects in casting, forming, and welding Inspection practices and NDT.

Introduction to additive manufacturing systems

Textbooks:

1. Beddoes, J. and Bibby, M. J., *Principles of Metal Manufacturing Processes*, Butterworth-Heinemann (1999).
2. Kalpakjian, S. and Schmidt, S. R., *Manufacturing Processes for Engineering Materials*, 5th ed., Pearson Education (2007).

References:

1. Ghosh, A. and Mallik, A. K., *Manufacturing Science*, Affiliated East West Press (2010).
2. Abbaschian, R., Abbaschian, L., and Reed-Hill, R. E., *Physical Metallurgy Principles*, 4th ed., Cengage Learning (2008).
3. Krishnadas Nair, C. G. and Srinivasan, R., *Materials and Fabrication Technology for Satellite and Launch Vehicle*, Navbharath Enterprises (2008).
4. Groover, M. P., *Fundamentals of Modern Manufacturing: Materials, Processes, and Systems*, 5th ed., Wiley-India (2012).

AE215 INTRODUCTION TO MACHINE ELEMENTS AND DRAWING (2 – 0 – 3) 3 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).

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

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

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

Basics of Macro Economics: components of macro economics – role of government – national income concepts – calculation of national income – inflation concepts – methods of calculation – classical vs. Keynesian – globalization.

Economic Problems and Policies: meaning of development – developing vs. developed countries – problems of growth – controversies – population and development – role of agriculture and industry – demographic transition – balance of payments – planning and growth.

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*, Government of India, Ministry of Finance.

7. O'Connor, D. E., *The Basics of Economics*, Greenwood Press (2004).

AE231	STRENGTH OF MATERIALS LAB	(0 – 0 – 3) 1 credit

Uniaxial tension test with loading/unloading of mild steel and aluminium alloy rods – Impact tests: Izod and Charpy tests – Torsion test – Double shear test – Compression test – Spring test – Deflection of beams – Simple bending tests.

SEMESTER IV

MA221 INTEGRAL TRANSFORMS, PDE, AND CALCULUS OF VARIATIONS (3 – 0 – 0) 3 credits

Integral Transforms: 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.

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.

Textbook:

- Kreyszig, E., *Advanced Engineering Mathematics*, 10th ed., John Wiley (2011).

References:

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

AE221 AERODYNAMICS (3 – 0 – 0) 3 credits

Aerodynamic forces and moments – review of governing equations – potential flows – Kutta condition – vortex theorems – thin airfoil theory – finite wing theory – panel methods – flow over delta wings – boundary layer theory – effect of pressure gradient – flow separation and stall – high-lift devices – structure of turbulent boundary layer – Reynolds averaging.

Textbook:

- Anderson, J. D., *Fundamentals of Aerodynamics*, 5th ed., McGraw-Hill (2010).

References:

1. Bertin, J. J. and Cummings, R. M., *Aerodynamics for Engineers*, 6th ed., Prentice Hall (2013).
2. Houghton, E. L., Carpenter, P. W., Collicott, S. H., and Valentine, D. T., *Aerodynamics for Engineering Students*, 6th ed., Butterworth-Heinemann (2012).
3. Kuethe, A. M. and Chow, C.-Y., *Foundations of Aerodynamics*, 5th ed., John Wiley (1997).
4. Clancy, L. J., *Aerodynamics*, Reprint ed., Himalayan Books (2006).
5. Drela, M., *Flight Vehicle Aerodynamics*, MIT Press (2014).

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 – introduction to boiling and condensation – heat exchangers – blackbody radiation and radiative properties – radiative exchange between surfaces.

Textbook:

- Bergman, T. L., Lavine, A. S., Incropera, F. P., and DeWitt, D. P., *Fundamentals of Heat and Mass Transfer*, 7th ed., John Wiley (2011).

Data Book:

- Kothandaraman, C. P. and Subramanyan, S., *Heat and Mass Transfer Data Book*, 8th ed., New Age International Pub. (2014).

References:

1. Holman, J. P., *Heat Transfer*, 10th ed., Tata McGraw-Hill (2010).
2. Çengel, Y. A. and Ghajar, A. J., *Heat and Mass Transfer: Fundamentals and Applications*, 5th ed., Tata McGraw-Hill (2014).

AE223 APPLIED DYNAMICS AND VIBRATION (3 – 0 – 0) 3 credits

Review of kinematics and dynamics of particles – kinematics and dynamics of rigid bodies – constraint dynamics applied to mechanisms – conservation laws for rigid bodies.

Vibration of single dof systems – response of single dof system to transient loadings – multi dof systems and mode superposition.

Textbooks:

1. Uicker, J. J., Pennock, G. R., and Shigley, J. E., *Theory of Machines and Mechanisms*, 4th ed., Oxford Univ. Press (2010).
2. Thomson, W. T. and Dahleh, M. D., *Theory of Vibrations with Applications*, 5th ed., Pearson Education (2008).

References:

1. Norton, R. L., *Kinematics and Dynamics of Machinery*, 1st SI Edition, Tata McGraw-Hill (2009).
2. Ghosh, A. and Mallik, A. K., *Theory of Mechanisms and Machines*, 3rd ed., Affiliated East-West Press (2011).
3. Dresig, H. and Holzweisig, F., *Dynamics of Machinery: Theory and Applications*, Springer (2010).
4. Tenenbaum, R. A., *Fundamentals of Applied Dynamics*, Springer (2004).

AE224 MACHINING SCIENCE and TECHNOLOGY (3 – 0 – 0) 3 credits

Significance of machining processes in engineering/aerospace applications Theory and mechanics of machining processes Abrasive based precision machining processes and applications Configuration and operation of general purpose machine tools

Machinability of aerospace materials- Selection of cutting tools and cutting parameters- Tribological aspects of machining- Design considerations and preparation of drawings for machining.

CNC machines and multi- axis machining Introduction to non-traditional (unconventional) manufacturing

Recent trends in machining technology for aerospace applications.

Textbooks:

1. Kalpakjian, S. and Schmidt, S. R., *Manufacturing Processes for Engineering Materials*, 5th ed., Pearson Education (2007).
2. Ghosh, A. and Mallik, A. K., *Manufacturing Science*, 2nd ed., Affiliated East-West Press (2010).

References:

1. Groover, M. P., *Fundamentals of Modern Manufacturing: Materials, Processes, and Systems*, 5th ed., Wiley-India (2012).
2. Juneja, B. L., Sekhon, G. S., and Seth, N., *Fundamentals of Metal Cutting and Machine Tools*, New Age International (2008).
3. Krishnadas Nair, C. G. and Srinivasan, R., *Materials and Fabrication Technology for Satellite and Launch Vehicle*, Navbharath Enterprises (2008).
4. Campbell, F. C., *Manufacturing Technology for Aerospace Structural Materials*, Elsevier (2006).
5. Venkatesh, V. C. and Izman, S., *Precision Engineering*, Tata McGraw-Hill (2007).

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

Introduction to Social Sciences: Natural science and social science – social science perspective: characteristics – the general theory of social science: Comte, Durkheim, Marx – subdivisions of social sciences: sociology, anthropology, ethnography, political science, economics, psychology and philosophy – social science and space.

Macrocosms: Social Structure, Society: society – different types of societies – culture, socialization, agencies of socialization – race, ethnicity – caste and tribe – transparency, civil society and good governance – femininities, masculinities and gender relations, sexuality and gender.

Microcosm: Problems of the Marginalized: tribal society – development induced displacement, poverty – women, increasing violence – children, foeticide & infanticide, unequal sex ratio, child marriage, child labour and trafficking – elderly in India – people with disabilities – sexual minorities.

Ethics: introduction to ethics – professional ethics – personal ethics.

References:

1. Perry, J. A. and Perry, E. K., *Contemporary Society: An Introduction to Social Science*, 13th ed., Routledge (2011).
2. Strada, M. J., *Through the Global Lens: An Introduction to Social Sciences*, 3rd ed., Prentice Hall (2008).
3. Ahuja, R., *Social Problems in India*, 3rd ed., Rawat Publications (2014).
4. Singer, P. (Ed.), *A Companion to Ethics*, Wiley-Blackwell (1993).
5. Martin, M. W. and Schinzinger, R., *Ethics in Engineering*, 4th ed., McGraw-Hill (2004).

Further Reading:

1. *Introduction to Sociology*, Wikibooks.
2. Flyvbjerg, B., *Making Social Science Matter: Why Social Inquiry Fails and How it Can Succeed Again*, Cambridge Univ. Press (2001).
3. Singleton Jr., R. A. and Straits, B. C., *Approaches to Social Research*, Oxford Univ. Press (2009).
4. Hutchinson, P., Read, R., and Sharrock, W., *There is No Such Thing as a Social Science: In Defence of Peter Winch*, Routledge (2008).

AE241 THERMAL AND FLUID LAB (0 – 0 – 3) 1 credit

Measurements using Pitot-static tube for gas (air) flow – Orifice-meter and venturi-meter for liquid (water) flow through pipe – Laminar and turbulent flow through pipes, pressure drop – Thermal conductivity measurements of solids – Heat transfer by radiation – Forced and natural convection – Heat exchangers: LMTD, pressure drop – heat transfer coefficient – Pump and turbine efficiencies – CoP of vapor compression refrigeration cycles – Efficiency and BHP of SI and CI engines – Performance test of compressors and blowers.

AE242 METROLOGY AND COMPUTER AIDED INSPECTION (1 – 0 – 3) 2 credits

Theory: Role of metrology in aerospace engineering and traditional measurement practices – measurements of form errors – limit gauges – comparators – surface roughness and related parameters.

Experiments: Lab practice on linear and angular measurements – optical measurements – measurement of screws/gears – measurement of form errors – measurement of roughness – inspection practices using comparators – interpretation of shop floor drawings and the related measurement exercises using typical engineering/aerospace components.

References:

1. Shotbolt, C. S. and Galyer, J., *Metrology for Engineers*, 5th ed., Cassell Pub. (1990).
2. Smith, G. T., *Industrial Metrology: Surfaces and Roundness*, Springer-Verlag (2002).
3. Bewoor, A. K. and Kulkarni, V. A., *Metrology & Measurement*, Tata McGraw-Hill (2009).
4. Busch, T., *Fundamentals of Dimensional Metrology*, 2nd ed., Delmar Pub. (1988).

SEMESTER V

MA311 PROBABILITY, STATISTICS, AND NUMERICAL METHODS (3 – 0 – 0) 3 credits

Probability Theory: Elementary concepts on probability – axiomatic definition of probability – conditional probability – Bayes' theorem – random variables – standard discrete and continuous distributions – moments of random variables – moment generating functions – multivariate random variables – joint distributions of random variables – conditional and marginal distributions – conditional expectation – distributions of functions of random variables – t and χ^2 distributions – Schwartz and Chebyshev inequalities – weak law of large numbers for finite variance case – central limit theorem for iid finite variance case.

Statistics: Elementary concepts on populations, samples, statistics – sampling distributions of sample mean and sample variance – point estimators and its important properties – point estimator for mean and variance and proportion – confidence interval for sample mean – tests of hypotheses – Chi-squared test of goodness of fit.

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

Textbooks:

1. Walpole, R. E., Myers, R. H., Myers, S. L., and Ye, K., *Probability & Statistics for Engineers & Scientists*, 9th ed., Pearson Education (2012).
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. Johnson, R. A., *Miller & Freund's Probability and Statistics for Engineers*, 6th ed., Prentice Hall (2000).
2. Milton, J. S. and Arnold, J. C., *Introduction to Probability and Statistics: Principles and Applications for Engineering and the Computing Sciences*, 4th ed., McGraw-Hill (2002).
3. Ross, S. M., *Introduction to Probability and Statistics for Engineers and Scientists*, 3rd ed., Academic Press (2004).
4. Hogg, R. V. and Tanis, E. A., *Probability and Statistical Inference*, 7th ed., Prentice Hall (2005).
5. Larsen, R. J. and Marx, M. L., *An Introduction to Mathematical Statistics and Its Applications*, 4th ed., Prentice Hall (2005).
6. Conte, S. D. and de Boor, C., *Elementary Numerical Analysis*, 3rd ed., TMH (2005).
7. Krishnamurthy, K. V., *Numerical Algorithms*, Affiliated East-West Press (1986).

AE311 COMPRESSIBLE FLOW (3 – 0 – 0) 3 credits

Governing equations – quasi-one-dimensional flows – acoustic waves and waves of finite amplitude – normal shocks – R-H equations – shock tube problem – oblique shocks – Prandtl-Meyer expansion – wave drag – reflection and interaction of waves – conical flows – flows with friction and heat transfer – linearized potential flow and its applications – transonic flows.

Textbook:

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

References:

1. Liepmann, H. W. and Roshko, A., *Elements of Gasdynamics*, Dover (2001).
2. John, J. E. A. and Keith, T., *Gas Dynamics*, 3rd ed., Prentice Hall (2006).
3. Zucker, R. D. and Biblarz, O., *Fundamentals of Gas Dynamics*, 2nd ed., Wiley (2002).
4. Saad, M. A., *Compressible Fluid Flow*, 2nd ed., Prentice Hall (1992).
5. Shapiro, A. H., *The Dynamics and Thermodynamics of Compressible Fluid Flow*, Vol. 1 & 2 Wiley (1953).

AE312 ATMOSPHERIC FLIGHT MECHANICS (3 – 0 – 0) 3 credits

Overview of aerodynamics, propulsion, atmosphere and aircraft instrumentation – aircraft performance: gliding, cruise and climbing flight, optimal cruise trajectories, take-off and landing, V-n diagrams – stability and control: static longitudinal, directional and lateral stability and control, stick fixed and stick free stability, hinge moments, trim-tabs, aerodynamic balancing – effect of manoeuvres – stability control and performance characteristics of sounding rockets and launch vehicles.

Textbooks:

1. Nelson, R. C., *Flight Stability and Automatic Control*, 2nd ed., Tata McGraw-Hill (1997).
2. Perkins, C. D. and Hage, R. E., *Airplane Performance Stability & Control*, Wiley (1949).

References:

1. Etkin, B. and Reid, L. D., *Dynamics of Flight: Stability and Control*, 3rd ed., Wiley (1996).
2. McCormick, B. W., *Aerodynamics, Aeronautics, and Flight Dynamics*, 2nd ed., 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).
5. Phillips, W. F., *Mechanics of Flight*, 2nd ed., John Wiley (2010).

AE313 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 – different methods of solution to Lambert problem.

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.

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).

References:

1. Wiesel, W. E., *Spaceflight Dynamics*, 2nd ed., McGraw-Hill (1996).
2. Brown, C. D., *Spacecraft Mission Design*, 2nd ed., AIAA Edu. Series (1998).
3. Escobal, P. R., *Methods of Orbit Determination*, 2nd ed., Krieger Pub. Co. (1976).
4. Tewari, A., *Atmospheric and Space Flight Dynamics: Modeling and Simulation with MATLAB and Simulink*, Birkhauser (2007).

AE314 THEORY OF ELASTICITY (3 – 0 – 0) 3 credits

Introduction to tensors – introduction to theory of elasticity – strain and stress descriptions – stress-strain relations – thermal stresses – plane stress and plane strain – stress functions – torsion of solid sections – virtual work-energy methods – fracture mechanics – introduction of dynamics of structures.

Textbook:

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

References:

1. Megson, T. H. G., *Aircraft Structures for Engineering Students*, 4th ed., Butterworth-Heinemann (2007).
2. Timoshenko, S. P. and Goodier, J. N., *Theory of Elasticity*, 3rd ed., McGraw-Hill (1970).

AV315 AUTOMATIC CONTROL (2 – 1 – 0) 3 credits

Examples of controlled systems, open loop and feedback control, control system components – modeling of physical systems, block diagrams – review of Laplace transform, transfer function – time domain and frequency domain responses – stability, poles and zeros, Routh-Hurwitz criterion – root locus – Bode plot, Nyquist criterion – PID controller, lead and lag compensators – examples from aerospace and mechanical systems – introductions to state-space representation – stability criterion – concepts of controllability and observabilty.

Textbook:

- D'Azzo, H., *Feedback Control System Analaysis and Synthesis*, CRC Press (2007).

References:

1. Ogata, K., *Modern Control Engineering*, 5th ed., Pearson Education (2009).
2. Gopal, M., *Control Systems: Principles and Design*, 3rd ed., Tata McGraw-Hill (2008).
3. Xue, D., Chen, YQ., and Atherton, D. P., *Linear Feedback Control Analysis and Design with MATLAB*, SIAM (2007).

AE331 AERODYNAMICS LAB (1 – 0 – 3) 2 credits

Theory: Types of wind tunnels – uncertainty analysis – measurement & flow visualization techniques – basics of data acquisition and signal processing.

Experiments: Measurement of lift and drag on airfoil and cylinder using various methods (pressure measurements, wake survey, and force balance) – flow visualization (smoke, oil, and optical) – free jet characteristics.

AE332 MANUFACTURING PROCESSES LAB (0 – 0 – 3) 1 credit

Exercises to study the fundamental aspects of machining operations applied in typical engineering/aerospace applications.

Practices in traditional metal cutting operations – CNC simulation training – CNC machine tool exercises – grinding exercises and related analysis – exercises in non-traditional machining.

Metal forming practice: welding exercises and metallurgical analysis/NDT of weld joints.

Understanding the basics of cutting force/cutting temperature measurement – flexible manufacturing system – machining centre and additive manufacturing.

SEMESTER VI

AE321 AIR-BREATHING PROPULSION (3 – 0 – 0) 3 credits

Introduction to combustion and flames – introduction to air breathing propulsion systems – engine thrust and performance parameters – aircraft engine types – ideal and real gas turbine cycle analysis – performance measures – engine-aircraft matching – aerothermodynamics of inlets, nozzles, combustion chambers and after burners – basics of turbomachinery – compressor and turbine blade flow path analysis (axial and centrifugal types) – engine component matching and off-design analysis – ram jets – hypersonic air-breathing engines.

Textbooks:

1. Farokhi, S., *Air Craft Propulsion*, 2nd ed., Wiley (2014).
2. Hill, P. G. and Peterson, C. R., *Mechanics and Thermodynamics of Propulsion*, 2nd ed., Pearson Education (2009).

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 (1994).
4. Dixon, S. L. and Hall, C. A., *Fluid Mechanics and Thermodynamics of Turbomachinery*, 7th ed., Butterworth-Heinemann (2013).

AE322 AEROSPACE STRUCTURES (3 – 0 – 0) 3 credits

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

Textbook:

- Sun, C. T., *Mechanics of Aircraft Structures*, 2nd ed., John Wiley (2006).

References:

1. Megson, T. H. G., *Aircraft Structures for Engineering Students*, 4th ed., Butterworth-Heinemann (2007).
2. Donaldson, B. K., *Analysis of Aircraft Structures: An Introduction*, 2nd ed., Cambridge Univ. Press (2008).

3. Bauchau, O. A. and Craig, J. I., *Structural Analysis: With Application to Aerospace Structures*, Springer (2009).
4. Timoshenko, S. P. and Woinowsky-Krieger, S., *Theory of Plates and Shells*, 2nd ed., McGraw-Hill (1964).
5. Ugural, A. C., *Stresses in Plates and Shells*, 2nd ed., McGraw-Hill (1998).

AE323 OPTIMIZATION TECHNIQUES IN ENGINEERING (3 – 0 – 0) 3 credits

Introduction to optimization – linear programming – duality and sensitivity analysis – integer programming – nonlinear programming – unconstrained optimization – constrained optimization: equality and inequality constraints – optimality conditions and optimization approaches – nontraditional optimization approaches – applications in aerospace engineering.

Textbooks:

1. Ravindran, A., Phillips, D. T., and Solberg, J. J., *Operations Research: Principles and Practice*, 2nd ed., Wiley-India (2006).
2. Rao, S. S., *Engineering Optimization: Theory and Practices*, 4th ed., John Wiley (2009).

References:

1. Winston, W. L., *Operations Research: Applications and Algorithms*, 4th ed., Cengage Learning (2010).
2. Ravindran, A., Ragsdell, K. M., and Reklaitis, G. V., *Engineering Optimization: Methods and Applications*, 2nd ed., Wiley-India (2006).
3. Deb, K., *Optimization for Engineering Design: Algorithms and Examples*, 2nd ed., PHI Learning (2012).
4. Deb, K., *Multi-Objective Optimization Using Evolutionary Algorithms*, Wiley-India (2010).

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

Industrial Management: development of management thought – management functions – planning – organizing power and authority – organization structures – span of control – delegation, leadership, directing and controlling – management by objectives – forecasting models – functional areas of management – entrepreneurship.

Personnel Management: characteristics of R&D projects – development of project network – project representation – project scheduling – linear time, cost trade-offs in projects – project monitoring and control with PERT – resource leveling – break even analysis – application of linear programming in resource allocations – simplex method.

Human Resource Management: personnel management – functions of HRM-assignment of people to projects – man power planning – workers participation in management-grievance handling – performance appraisal – organizing for maximum performance: quality of work life, job rotation, job enrichment.

References:

1. Koontz H., O'Donnel, 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. Mamoria, C. B. and Rao, V. S. P., *Personnel Management: Text and Cases*, 27th ed., Himalaya Publishing House (2015).

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

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

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

Hardness tests: Brinell hardness, Vickers hardness, Rockwell hardness – 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.

AE342 MODELING AND ANALYSIS LAB (1 – 0 – 3) 2 credits

- Modeling and analysis using FEM: Geometric modeling and finite element meshing of beam, plate and solid structures – stress, free vibration and buckling analyses
- Modeling and simulation of multi-rigid body systems using Scilab/MATLAB/ADAMS
- Modeling of heat transfer and fluid flow

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 – combustion instability – 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.

Textbooks:

1. Ramamurthi, K., *Rocket Propulsion*, Macmillan (2010).
2. Sutton, G. P. and Biblarz, O., *Rocket Propulsion Elements*, 7^{th} ed., John Wiley (2000).

References:

1. Hill, P. G. and Peterson, C. R., *Mechanics and Thermodynamics of Propulsion*, 2^{nd} ed., Pearson Education (2009).
2. Mattingly, J. D., *Elements of Propulsion: Gas Turbines and Rockets*, AIAA Edu. (2006).

AE412	AEROSPACE VEHICLE DESIGN	(2 – 0 – 3) 3 credits

Introduction to the design process – requirements capture – design optimization.

Aircraft Design: design considerations for civilian and military aircraft – 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 – aircraft layout and configuration – structural aspects – constraint analysis.

Space Vehicle Design: requirements, specifications and design process – rocket equation – velocity budget, staging, launch vehicle sizing, launch into an orbit, range safety – rocket propulsion options – configuration and structural design – NGC systems – thermal control – power systems – communication systems – design for reentry – vehicle integration and recovery.

Textbooks:

1. Sadraey, M. H., *Aircraft Design: A Systems Engineering Approach*, Wiley (2012).
2. Griffin, M. D. and French, J. R., *Space Vehicle Design*, 2^{nd} ed., AIAA Edu. Series (2004).

References:

1. Raymer, D. P., *Aircraft Design: A Conceptual Approach*, 4^{th} ed., AIAA Edu. Series (2006).
2. Anderson, J. D., *Aircraft Performance and Design*, McGraw-Hill (1999).

3. Corke, T. C., *Design of Aircraft*, Prentice Hall (2002).
4. Fielding, J. P., *Introduction to Aircraft Design*, Cambridge Univ. Press (1999).
5. Bruhn, E. F., *Analysis and Design of Flight Vehicle Structures*, Jacobs Publishing (1973).
6. Niu, M. C. Y., *Airframe Structural Design: Practical Design Information and Data on Aircraft Structures*, 2nd ed., Adaso/Adastra Engineering Center (1999).

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:

Simulation of accelerated maneuvers using whirling arm – Estimation of aerodynamics derivatives from wind tunnel test – Flight simulation using open source flight simulator – Study of helicopter flight control mechanism – Flight test on UAV.

Propulsion:

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.

AV435	INSTRUMENTATION AND CONTROL SYSTEMS LAB	(1 – 0 – 3) 2 credits

Theory: Mathematical modelling of electromechanical and electrohydraulic actuation systems, control system specifications and compensator design approaches – Basics of instrumentation systems and transducers, classification of transducers and static characteristics, instrumentation amplifiers and filtering circuits.

Experiments: Familiarization with MATLAB and SIMULINK – Linear system modelling, simulation, analysis and compensator design for different types of actuation systems – Nonlinear system modelling, simulation, and performance assessment – Static characterization of resistive, inductive, and capacitive transducers.

AE451	SUMMER INTERNSHIP AND TRAINING	3 credits

SEMESTER VIII

AE453	COMPREHENSIVE VIVA-VOCE	3 credits

AE454	PROJECT WORK	12 credits

ELECTIVES

AE460	AEROACOUSTICS	(3 – 0 – 0) 3 credits

Basics of acoustics – general theory of aerodynamic sound – flow and acoustic interactions – feedback phenomenon – supersonic jet noise – sonic boom – noise radiation from rotors and fans – aeroacoustic measurements.

References:

1. Pierce, A. D., *Acoustics: An Introduction to Its Physical Principles and Applications*, Acoustical Society of America (1989).
2. Dowling, A. P. and Ffowcs Williams, J. E., *Sound and Sources of Sound*, Ellis Horwood (1983).
3. Goldstein, M. E., *Aeroacoustics*, McGraw-Hill (1976).
4. Blake, W. K., *Mechanics of Flow-Induced Sound and Vibration, Volume I and II*, Academic Press (1986).
5. Crighton, D. G., Dowling, A. P., Ffowcs Williams, J. E., Heckl, M. A., and Leppington, F. A., *Modern Methods in Analytical Acoustics: Lecture Notes*, Springer-Verlag (1992).

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

Panel methods – unsteady potential flows – compressible flow over wings – axisymmetric flows and slender body theories – flight vehicle aerodynamics – rotor aerodynamics – low Reynolds number aerodynamics – flapping wings – two- and three-dimensional flow separation.

References:

1. Drela, M., *Flight Vehicle Aerodynamics*, MIT Press (2014).
2. Rom, J., *High Angle of Attack Aerodynamics: Subsonic, Transonic, and Supersonic Flows*, Springer-Verlag (1992).
3. Shyy, W., Aono, H., Kang, C.-K., and Liu, H., *An Introduction to Flapping Wing Aerodynamics*, Cambridge Univ. Press (2013).
4. Chattot, J. J. and Hafez, M. M., *Theoretical and Applied Aerodynamics: and Related Numerical Methods*, Springer (2015).
5. Bisplinghoff, R. L., Ashley, H., and Halfman, R. L., *Aeroelasticity*, Dover (1996).
6. Telionis, D. P., *Unsteady Viscous Flows*, Springer (2012).

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*, 4th ed., John Wiley (2013).
3. Kundu, P. K., Cohen, I. M., and Dowling, D. R., *Fluid Mechanics*, 6th ed., Academic Press (2015).
4. Leal, L. G., *Advanced Transport Phenomena: Fluid Mechanics and Convective Transport Processes*, 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 – finite volume method – Burgers equation – time integration schemes – incompressible Navier-Stokes equations and their solution algorithms.

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

References:

1. Kakac, S., Yener, Y., and Pramuanjaroenkij, A., *Convective Heat Transfer*, 3rd ed., CRC Press (2014).
2. Kays, W. M. and Crawford, M. E., *Convective Heat and Mass Transfer*, 2nd ed., McGraw-Hill (1980).

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

Concept of similarity and design of experiments – measurement uncertainty – design of subsonic, transonic, supersonic, hypersonic, and high enthalpy test facilities – transducers and their response characteristics – measurement of pressure, temperature, velocity, forces, moments and dynamic stability derivatives – flow visualization techniques: optical measurement techniques, refractive index based measurements, scattering based measurements – data acquisition and signal conditioning – signal and image processing.

References:

1. Tropea, C., Yarin, A., and Foss, J. F. (Eds.), *Springer Handbook of Experimental Fluid Mechanics*, Springer (2007).
2. Barlow, J. B., Rae Jr, W. H., and Pope, A., *Low-Speed Wind Tunnel Testing*, 3rd ed., Wiley (1999).
3. Pope, A. and Goin K., *High-Speed Wind Tunnel Testing*, Krieger Pub. Co. (1978).
4. Settles, G. S., *Schlieren and Shadowgraph Techniques: Visualizing Phenomena in Transparent Media*, Springer (2001).
5. Mayinger, F. and Feldmann, O. (Eds.), *Optical Measurements: Techniques and Applications*, 2nd ed., Springer (2001).
6. Doebelin, E. O., *Measurement Systems: Application and Design*, 5th ed., McGraw-Hill (2003).

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*, PHI Learning (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*, 9th ed., Pearson (2010).
3. Sharma, J. K., *Operations Research*, Macmillan (1997).

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

Combustion and thermochemistry – fuels – chemical kinetics and mechanisms – reacting flows – modeling of reacting flows – premixed flames – detonation and explosion – introduction to turbulence – turbulent premixed combustion – non-premixed combustion – turbulent non premixed combustion – spray combustion – combustion instability.

Textbook:

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

References:

1. Glassman, I. and Yetter, R. A., *Combustion*, 4th ed., Academic Press (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 SOLAR THERMAL ENERGY (3 – 0 – 0) 3 credits

Introductory aspects of non-renewable and renewable energy sources – fundamentals of thermal radiation – resource assessment – solar radiation concepts – solar-earth geometry – models to predict global and daily and hourly irradiation.

Solar collection theory and technologies (non-concentrating): heat transfer in solar collectors – basic modeling aspects – steady and dynamic analysis – performance parameters.

Solar concentration systems and receivers: overview and introduction to concentration optics – concentration ratio and thermodynamic maximum – linear concentration: trough and linear Fresnel – point concentration: dish and tower (central receiver system).

Thermal storage: need for thermal storage – methods – simple models.

Solar power generation systems: overview and types of systems – components and sub systems – aspects of design and performance prediction.

Solar cooling: solar liquid absorption and solar solid sorption technologies.

References:

1. Boyle, G., *Renewable Energy: Power for a Sustainable Future*, 3rd ed., Oxford Univ. Press (2012).
2. Duffie, J. A. and Beckman, W. A., *Solar Engineering of Thermal Processes*, John Wiley (1991).
3. Sukhatme, S. P. and Nayak, J. K., *Solar Energy: Principles of Thermal Collection and Storage*, 3rd ed., McGraw-Hill (2009).

AE480 BOUNDARY LAYER THEORY (3 – 0 – 0) 3 credits

Derivation of basic equations for viscous fluid flow, including heat conduction and compressibility – exact solutions.

Laminar boundary layer approximations – similar and non-similar boundary layers – momentum integral methods – separation of boundary layer – compressible boundary layer equations – recovery factor – Reynolds analogy – similar solutions.

Introduction to transition of laminar boundary layers.

Turbulent flows – phenomenological theories – Reynolds stress – turbulent boundary layer – momentum integral methods – turbulent free shear layer.

Introduction to axisymmetric and three-dimensional boundary layers.

References:

1. Schlichting, H. and Gersten, K., *Boundary Layer Theory*, 8th ed., McGraw-Hill (2001).
2. Batchelor, G. K., *Introduction to Fluid Dynamics*, 2nd ed., Cambridge Univ. Press (2000).
3. White, F. M., *Viscous Fluid Flow*, 3rd ed., McGraw-Hill (2006).
4. Cebeci, T. and Smith, A. M. O., *Analysis of Turbulent Boundary Layers*, Academic Press (1974).
5. Gatski, T. B. and Bonnet, J.-P. *Compressibility, Turbulence and High Speed Flow*, 2nd ed., Academic Press (2013).

AE481 OPERATIONS RESEARCH (3 – 0 – 0) 3 credits

Introduction – linear programming – duality and sensitivity analysis – transportation and assignment problems – goal programming – integer programming – network optimization models – dynamic programming – theory of games – queuing theory – simulation – nontraditional optimization algorithms.

Textbook:

1. Taha, H. A., *Operations Research: An introduction*, 9th ed., Pearson (2010).

References:

1. Ravindran, A., Phillips, D. T., and Solberg, J. J., *Operations Research: Principles and Practice*, 2nd ed., Wiley-India (2006).
2. Winston, W. L., *Operations Research: Applications and Algorithms*, 4th ed., Cengage Learning (2010).
3. Sharma, J. K., *Operations Research: Theory and Applications*, 4th ed., Macmillan Publishers (2009).

AE482 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).

AE483 INTRODUCTION TO ROBOTICS (2 – 0 – 3) 3 credits

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

Experiments: (a) manipulator kinematics (accuracy, inverse kinematics, task planning), (b) feedback control of simple manipulator, (c) motion control of wheeled mobile robots, and (d) path planning with obstacles.

References:

1. Siciliano, B., Sciavicco, L., Villani, L., and Oriolo, G., *Robotics: Modelling, Planning and Control*, Springer (2010).
2. Ghosal, A., *Robotics: Fundamental Concepts and Analysis*, Oxford Univ. Press (2006).
3. Choset, H., Lynch, K. M., Hutchinson, S., Kantor, G., Burgard, W., Kavraki, L. E., and Thrun, S., *Principles of Robot Motion: Theory, Algorithms, and Implementations*, MIT Press (2005).
4. Jazar, R. N., *Theory of Applied Robotics: Kinematics, Dynamics, and Control*, 2^{nd} ed., Springer (2010).
5. Merlet, J.-P., *Parallel Robots*, 2^{nd} ed., Springer (2006).
6. Siegwart, R., Nourbakhsh, I. R., and Scaramuzza, D., *Introduction to Autonomous Mobile Robots*, 2^{nd} ed., MIT Press (2011).
7. Siciliano, B. and Khatib, O. (Eds.), *Springer Handbook of Robotics*, Springer (2008).

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 (2002).

References:

1. Chobotov, V., *Orbital Mechanics*, AIAA Edu. Series (2002).
2. Griffin, M. D. and French, J. R., *Space Vehicle Design*, 2^{nd} 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. (Eds.), *Optimal Control: Calculus of Variations, Optimal Control Theory and Numerical Methods*, Birkhauser Verlag (1993).

AE485 MOLECULAR DYNAMICS AND MATERIALS FAILURE (3 – 0 – 0) 3 credits

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

References:

1. Buehler, M. J., *Atomistic Modeling of Materials Failure*, Springer (2008).
2. Frenkel, D. and Smit, B., *Understanding Molecular Simulation: From Algorithms to Applications*, 2^{nd} ed., Academic Press (2001).
3. Rapaport, D. C., *The Art of Molecular Dynamics Simulation*, 2^{nd} ed., Cambridge Univ. Press (2004).

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*, 2^{nd} 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

Introduction to Turbomachines. Dimensional Analyses and Performance Laws.

Axial Flow Compressors and Fans: Introduction – aero-thermodynamics of flow through an axial flow compressor stage – losses in axial flow compressor stage – losses and blade performance estimation, radial equilibrium equation – design of compressor blades – 2-D blade section design, axial compressor characteristics – multi-staging of compressor characteristics – high Mach number compressor stages – stall and surge phenomenon – low speed ducted fans.

Axial Flow Turbines: Introduction – turbine stage – turbine blade 2-D (cascade) analysis work done – degree of reaction – losses and efficiency – flow passage – subsonic, transonic and supersonic turbines – multi-staging of turbine – exit flow conditions – turbine cooling – turbine blade design – turbine profiles, airfoil data and profile construction.

Centrifugal Compressors: Introduction – elements of centrifugal compressor/fan – inlet duct impeller – slip factor – concept of rothalpy – modified work done – incidence and lag angles – diffuser – centrifugal compressor characteristics – surging, chocking, rotating stall.

Radial Turbine: Introduction – thermodynamics and aerodynamics of radial turbines – radial turbine characteristics – losses and efficiency.

References:

1. Cumpsty, N. A., *Compressor Aerodynamics*, 2nd ed., Krieger Pub. Co. (2004).
2. Johnsen, I. A. and Bullock, R. O. (Eds.), *Aerodynamic Design of Axial-Flow Compressors*, NASA SP-36 (1965).
3. El-Wakil, M. M., *Powerplant Technology*, McGraw-Hill (1985).
4. Glassman, A. J. (Ed.), *Turbine Design and Application*, NASA SP-290 (1972).
5. Lakshminarayana, B., *Fluid Dynamics and Heat Transfer of Turbomachinery*, Wiley (1995).
6. El-Sayed, A. F., *Aircraft Propulsion and Gas Turbine Engines*, CRC Press (2008).
7. Dixon, S. L. and Hall C. A., *Fluid Mechanics and Thermodynamics of Turbomachinery*, 7th ed., Butterworth-Heinemann (2014).

AE488 PRECISION ENGINEERING AND AUTOMATION (3 – 0 – 0) 3 credits

Precision engineering requirements in aerospace applications-Manufacturing techniques and hybrid strategies for precision applications- Elements of precision machining systems- Drive systems- Guide ways- Bearings- Sensors and Actuators- Feedback systems and adaptive control configurations- Elements of mechatronic systems and modelling- Micro manufacturing and smart manufacturing for precision applications - Micro electro mechanical systems for aerospace applications- Assembly automation for industrial applications- product design for automation - automated inspection - PLC/micro controller programming and applications in automation/precision engineering.

Textbooks:

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

Introduction Spacecraft Thermal Control: need of spacecraft thermal control – temperature specification – energy balance in a spacecraft – modes of heat transfer – factors that influence energy balance in a spacecraft – principles of spacecraft thermal control.

Spacecraft Thermal Analysis: formulation of energy – momentum and continuity equations for problems in spacecraft heat transfer – development of discretized equation – treatment of radiative heat exchange (for non-participative media based on radiosity and Gebhart method) – incorporation of environmental heat flux in energy equation – numerical solution methods – input parameters required for analysis.

Spacecraft Thermal Environments: launch and ascent – earth bound orbits – interplanetary mission and reentry mission.

Devices and Hardware for Spacecraft TCS (Principles & Operation): passive thermal control - mechanical joints – heat sinks and doublers – phase change materials – thermal louvers and switches – heat pipes – thermal coating materials – thermal insulation – ablative heat transfer – active thermal control techniques: electrical heaters, HPR fluid systems, space borne cooling systems.

Design and Analysis of Spacecraft: application of principles described above for development of spacecraft TCS.

References:

1. Incropera, F. P. and DeWitt, D. P., *Fundamentals of Heat and Mass Transfer*, 7th ed., John Wiley (2011).
2. Chapra, S. C. and Canale, R. P., *Numerical Methods for Engineers*, 7th ed., McGraw-Hill (2014).
3. Pattan, B., *Satellite Systems: Principles and Technologies*, Chapman & Hall (1993).
4. Meyer, R. X., *Elements of Space Technology*, Academic Press (1999).
5. Gilmore, D. G. (Ed.), *Spacecraft Thermal Control Handbook, Volume I: Fundamental Technologies*, 2nd ed., The Aerospace Press, AIAA (2002).

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).

AE823 HYPERSONIC AEROTHERMODYNAMICS (3 – 0 – 0) 3 credits

Introduction to Hypersonic Flows, Inviscid hypersonic flow: Newtonian flow, Mach number independence, hypersonic similarity, blast wave theory, hypersonic small disturbance theory, stagnation region flow. Viscous hypersonic flow: similarity parameters, self-similar solutions, hypersonic turbulent boundary layer, reference temperature method, stagnation region flow field, viscous interactions. Real Gas: inviscid equilibrium and non-equilibrium flows, viscous high temperature flows. Experimental facilities. Hypersonic design considerations.

References:

1. Anderson, J. D., *Hypersonic and High-Temperature Gas Dynamics*, 2nd ed., AIAA (2000).
2. Rasmussen, M., *Hypersonic Flow*, Wiley (1994).
3. Bertin, J. J., *Hypersonic Aerothermodynamics*, AIAA (1994).
4. Hirschel, E. H., *Basics of Aerothermodynamics*, Springer (2005).
5. Hirschel, E. H., *Selected Aerothermodynamic Design Problems of Hypersonic Vehicles*, Springer (2009).

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 INTRODUCTION TO FLOW INSTABILITY (3 – 0 – 0) 3 credits

Introduction to stability – review of dynamical systems concepts – instabilities of fluids at rest – stability of open shear flows: inviscid theory and viscous theory, spatio-temporal stability analysis (absolute and convective instabilities) – parabolized stability equation – transient growth – introduction to global instabilities.

References:

1. Charru, F., *Hydrodynamic Instabilities*, Cambridge Univ. Press (2011).
2. Drazin, P. G., *Introduction to Hydrodynamic Stability*, Cambridge Univ. Press (2002).
3. Drazin, P. G. and Reid, W. H., *Hydrodynamic Stability*, 2nd ed., Cambridge Univ. Press (2004).
4. Criminale, W. O., Jackson, T. L., and Joslin, R. D., *Theory and Computation of Hydrodynamic Stability*, Cambridge Univ. Press (2003).
5. Schmid, P. J. and Henningson, D. S., *Stability and Transition in Shear Flows*, Springer (2001).
6. Sengupta, T. K., *The Instabilities of Flows and Transition to Turbulence*, CRC Press (2012).

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	ENERGY METHODS IN ENGINEERING	(3 – 0 – 0) 3 credits

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).

NEW THEORY OF PLASTICITY AND METAL FORMING (3 – 0 – 0) 3 credits

Concepts of stress and strain, state of stress in two and three dimensions, Hydrostatic and deviatoric stress, flow curves, yielding criteria, octahedral shear stress and shear strain, stress invariants, Plastic stress - strain relations, Fundamentals of metal working - Extrusion, rolling, wire drawing, Forging, Mechanics of meal working by slab method, Tension testing.

References:

1. George E.Dieter, Mechanical Metallurgy, McGraw Hill Education; Third edition (1 July 2017)
2. Thomas Courtney, Mechanical Behaviour of materials, Waveland Press, Inc.; 2 edition
3. Andrzej Sluzalec, Theory of Metal Forming Plasticity: Classical and Advanced Topics, Springer; 1st ed. 2004 edition
4. Chakrabarty, Theory of plasticity, Elsevier; Third edition (20 August 2007)
5. Sadhu Singh, Theory of Plasticity and Metal Forming Processes, Khanna Publishers (2003)

NEW HUMAN BEHAVIOUS IN ORGANIZATIONS (3 – 0 – 0) 3 credits

Introduction - foundations of individual behavior and processes: personality, perception, work-place values, attitudes and emotions, learning, employee motivation, stress management - Group processes: foundations of group behavior, understanding work teams, communication, decision making and employee involvement, leadership, power and politics, conflict and negotiation - Organizational Processes: organization structure and design, organizational culture, organizational change and development.

References:

1. Stephen P. Robbins and Timothy A. Judge, Organizational behaviour, Pearson education, 16th edition, 2015.
2. Jerald Greenberg and Robert A. Barron, Behaviour in organizations, Prentice Hall, 10th edition, 2010.
3. Steven Mc Shane and Mary Von Glinov, Organizational behaviour, Mc Graw Hill, 7th edition, 2014.
4. John W. Newstrom and Keith Davis, Organizational behaviour: humanwork, Tata Mc Graw Hill, 11th edition, 2002

NEW	INTRODUCTION TO SPACE LAWS	(3 – 0 – 0) 3 credits

Introduction to international law; Space law - UNCOPUOS and its sub-committees and treaty formulation, definition and delimitation of outer space; Sources of space law - UN treaties, principles and resolutions, and domestic space legislations; Other international agencies relevant to space law; Legal aspects of space activities - state responsibility for space activities, debris mitigation; Legal and policty aspects of space applications - SATCOM policy, remote sensing data policy, position and navigation services, legal issues in satellite based services; Space Law relating to commercial space activities; Legal issues in emerging trends of space activities - Human space flight, tourism, resource utilization, small satellite constellations, IPR.

Textbooks:

1. FranciS LyaLL and Paul B. LarSen, 'Space Law - A treatise', Ashgate publishing Limited, England 2009.
2. I. H. Ph. Uiederiks-Verschoor, . V. Kopal, 'An introduction to space law' Kluwer Law International, 2008.
3. V.S Mani, S.Bhatt, V.Balakista Reddy, 'Recent trends in international space law and policy' Asia Law house, 2016.

References:

1. Frans von der Dunk, Fabio Tronchetti, ' Handbook of space law', Edward Elgar Publishing Limited, UK, 2015.
2. R. Venkata Rao V. Gopalkrishnan, Kumar Abhijeet, 'Recent Developments in Space Law - Opportunities & Challenges', Springer 2019.
3. Rahul Jairam Nikam, Tanja Masson Zwaan, V.Balakista Reddy, 'Space Activities and IPR Protection', Asia Law House, 2013.

NEW	NUMERICAL METHODS FOR SCIENTIFIC COMPUTING	(3 – 0 – 0) 3 credits

Mathematical review and computer arithematic - numbers and errors; Nonlinear equations; Direct methods for linear systems; Iterative Methods for Linear Systems; Eigenvalues and Eigenvectors - power method, inverse power method, QR method; Approximation Theory - norms, orthogonalization, polynomial approximation, piecewise polynomial approximation, trignometic approxiation, rational approximation, wavelet bases; Numerical Differentiation; Numerical Integration - Romberg Integration, Gauss Quadrture, Adaptive Quadrature; Numerical Ordinary Differential Equations - single step and multi-step methods, Runge-Kutta method, predictor-corrector method, stiffness, stability, shooting methods; Introduction to parallel programming - system architectures, shared and distributed memory programming, performance.

References:

1. John A. Trangenstein, 'Scientific Computing - Vol I, II, III', Springer, 2010.
2. Parviz Moin, Fundamentals of Engineering Numerical Analysis, Cambridge, 2010.
3. Steven C. Chapra, Applied Numerical Methods, McGraw Hill, 2012.
4. Walter Gander, Martin J. Gander, Felix Kwok, Scientific Computing, Springer, 2010.
5. A.S. Ackleh, E.J. Allen, R.B. Hearfott, P. Seshiyer, Modern Numerical Analysis, CRC, 2009.
6. Amos Gilat, Vish Subramaniam, Numerical Methods for Engineers and Scientists, Wiley, 2014.