Indian Institute of Space Science and Technology

Thiruvananthapuram

B.Tech. Aerospace Engineering
Curriculum and Syllabus
(Effective from 2022 Admission)

Department of Aerospace Engineering

Program Educational Objectives (PEO)

1. Obtain employment in space industry and other allied sectors.
2. Pursuing graduate studies and carry out research.
3. Engage in entrepreneurship and generate employment opportunities in the society.
4. Develop techno-managerial leadership skills.

Program Specific Outcomes (PSO)

1. To create highly qualified engineers with profound understanding in the areas of aerodynamics, flight mechanics, thermal engineering, propulsion, structure, design combined with materials and manufacturing technology and industrial engineering.
2. Enhance effective technical communication by written, oral, and group interactions through design projects.
3. Develop practical and applied skills through experiments, simulations, lab activities and programing skills.
4. Design and Modeling of Aerospace and allied systems and components.

Program Outcomes (PO): (Defined by NBA)

Engineering Graduates will be able to:

1. **Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2. **Problem analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. **Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4. **Conduct investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5. **Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
6. **The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

7. **Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

8. **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

9. **Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

10. **Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

11. **Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

12. **Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

SEMESTER I

CODE	TITLE	L	T	P	C
MA111	Calculus	3	1	-	4
MA112	Computer Programming and Applications	2	-	3	3
PH111	Physics I	3	1	-	4
CH111	Chemistry	2	1	-	3
AE111	Introduction to Aerospace Engineering	3	-	-	3
HS111	Communication Skills	2	-	3	3
PH131	Physics Lab	-	-	3	1
AE131	Basic Engineering Lab	-	-	3	1
	Total	15	3	12	22

SEMESTER II

CODE	TITLE	L	T	P	C
MA121	Vector Calculus and Ordinary Differential Equations	2	1	-	3
PH121	Physics II	3	1	-	4
CH121	Materials Science and Metallurgy	3	-	-	3
AV121	Data Structures and Algorithms	3	1	-	4
AV122	Basic Electrical and Electronics Engineering	3	1	-	4
AE141	Engineering Graphics	1	-	3	2
CH141	Chemistry Lab	-	-	3	1
	Total	15	4	6	21

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
HS211	Introduction to Economics	2	-	-	2
AE231	Strength of Materials Lab	-	-	3	1
AE232	Machine Drawing	-	-	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	Modeling and Analysis Lab	1	-	3	2
	Total	19	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
AE342	Manufacturing Processes Lab	-	-	3	1
	Total	18	0	6	20

SEMESTER VII

CODE	TITLE	L	T	P	C
AE411	Rocket Propulsion	3	-	-	3
AE412	Aerospace Vehicle Design	2	-	3	3
AE413	Optimization Techniques in Engineering	3	-	-	3
CH411	Environmental Science and Engineering	2	-	-	2
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
AE432	Summer Internship and Training	-	-	-	3
	Total	16/17	0	9	22/23

SEMESTER VIII

CODE	TITLE	L	T	P	C
AE441	Comprehensive Viva-Voce	-	-	-	3
AE442	Project Work	-	-	-	12
	Total	0	0	0	15

SEMESTER–WISE CREDITS

Semester	I	II	III	IV	V	VI	VII	VIII	Total
Credits	22	21	19	20	22	20	22/23	15	161/162

NOTE: Minimum credit to be earned for B.Tech. degree in Aerospace Engineering: 161

LIST OF ELECTIVES

CODE	TITLE
AE447	Multi-Rigid Body Dynamics
AE448	Analytical Methods in Thermal and Fluid Science
AE449	Robot Mechanisms and Technology
AE450	Optical and Laser Based Combustion Diagnostics
AE451	Physiological Fluid Mechanics
AE452	Random Vibrations and Applications
AE453	Rotordynamics
AE454	Experimental Modal Analysis
AE455	Theory of Plasticity and Metal Forming
AE456	Numerical Methods for Scientific Computing
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 and Analysis of Aerospace Structures
AE471	Convective Heat Transfer
AE472	Experimental Aerodynamics
AE473	Finite Element Method
AE474	Fracture Mechanics

AE475	Introduction to Space Laws*
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	Advanced Manufacturing and Automation
AE489	Aerospace Materials and Processes
AE490	Heat Transfer in Space Applications
AE491	Human Behaviour in Organizations
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

*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'Hospital's rule – infinite series – convergence –geometric series – tests of convergence (nth 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 – Taylor's 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*, 7th ed., Cengage Learning (2010).
2. Jain, R. K. and Iyengar, S. R . K., *Advanced Engineering Mathematics*, 4th ed., Alpha Science Intl. Ltd. (2013).

References:

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

Course Outcomes (COs):

CO1: Understand the importance of convergence of sequences and series to learn the solutions of some physical systems that are governed by Mathematical rules.

CO2: Enable students to use these notions to choose an appropriate model that is ideal for some real life situations and solve them.

CO3: Realize the importance of the concepts like limit, continuity and differentibility in modelling and solving many practical problems.

CO4: Evaluate defenite integrals, areas of curved regions, arc length of a curve, volume and the surface area of revolution, and the center of mass in various dimensions.

MA112 **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.

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 Mc Graw-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).

Course Outcomes (COs):

CO1: Learn the procedural and object oriented paradigm with conditional statements, looping constructs and functions.

CO2: Understand the concepts of streams, classes, functions, data and objects.

CO3: Understand dynamic memory management techniques using pointers, constructors, destructors, etc

CO4: Apply the concept of function overloading, operator overloading, virtual functions and polymorphism.

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, centerof 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.

Textbooks:

- 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*, 5^{th} ed., Thomson Brooks/Cole (2012).
2. Halliday, D., Resnick, R., and Walker, J., *Fundamentals of Physics*, 9^{th} ed., Wiley (2010).
3. Young, H. D., Freedman, R. A., Sundin, T. R., and Ford, A. L., *Sears and Zemansky's University Physics*, 13^{th} ed., Pearson Education (2011).

Course Outcomes (COs):

CO1: Introduction to the necessary mathematical tools and their applications to the formulation and solution of mechanics problems involving central forces and rigid bodies.

CO2: Introduction to special theory of relativity and its consequences.

CO3: To open the gateway to modern physics by introducing the basics of quantum mechanics and its application to simple systems.

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 thermo chemistry – liquid propellants – oxidizers and fuels– solid propellants – composite solid propellants.

Textbooks:

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

References:

1. Laidler, K. J., *Chemical Kinetics*, 3^{rd} 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*, 4^{th} ed., Wiley (2008).
4. Bockris, J. O'M. and Reddy, A. K. N., *Modern Electrochemistry 1: Ionics*, 2^{nd} ed., Springer (1998).

Course Outcomes (COs):

CO1: Understand and appreciate the applications of chemical kinetics in industry as well as in atmospheric science.

CO2: Design/ choose materials/ systems and conditions for applications in engineering fields, understanding the basics of electrochemistry and corrosion.

CO3: Knowledge in spectroscopic technique imparting confidence to work on novel materials for different applications.

CO4: Appreciate the role of propellants in space crafts and related systems.

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

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

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

References:

1. Anderson, D. F. and Eberhardt, S., *Understanding Flight*, 2nd ed., McGraw Hill (2009).
2. Anderson, J. D., *Introduction to Flight*, 7th ed., McGraw Hill (2011).
3. Szebehely, V. G. and Mark, H., *Adventures in Celestial Mechanics*, 2nd ed., Wiley (1998).
4. Turner, M. J. L., *Rocket and Spacecraft Propulsion: Principles, Practice and New Developments*, 3rd ed., Springer (2009).

Course Outcomes (COs):

CO1: Understanding the fundamental ideas of aerospace engineering.
CO2: Identify the various types of aircraft and engines, including their components and purposes.
CO3: Understanding fundamental aerodynamics, flight mechanics, and propulsion concepts.
CO4: Understand and use the International Standard Atmosphere.
CO5: Evaluate the forces and moments..
CO6: Relationships between different disciplines.

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).

Course Outcomes (COs):

CO1: Understand and learn the significance of Effective Communication Skills through learning life skills which are not hinged on traditional pedagogy.

CO2: Improved listening, speaking, reading and writing skills and confidence to become successful English speakers.

CO3: Understand significance of verbal and non-verbal communication in their personal and professional life

CO4: Enhance the students body language, social etiquette, presentation skills, interview skills, assertive communication skills, active listening and technical writing skills.

CO5: Develop critical and creative thinking by becoming active components in the nation building.

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.

Course Outcomes (COs):

CO1: Introduction to the methods of experimental physics. To learn how to set up an experiment to test a hypothesis.

CO2: Familiarization with the methods of curve fitting of experimental data and error analysis.

CO3: To perform experiments that apply the theoretical knowledge acquired in Physics I and Physics II courses.

AE131 **BASIC ENGINEERING LAB** (0 – 0 – 3) 1 Credit

Study of general purpose hand tools in engineering workshop – Assembly and disassembly practices: gear box assembly, Centrifugal pump assembly along with shaft alignment, Cam and follower mechanisms, Transducer (sensor) trainer – Experiments on different basic machines: lathe, milling and drilling – Welding practice – Electrical wiring and soldering practice.

Course Outcomes (COs):

CO1: Familiarization of basic mechanical elements, assemblies and mechanisms.

CO2: Familiarization of hand tools, cutting tools and measuring instruments used in Engineering workshop.

CO3: Familiarization of general purpose machines and processes in Engineering Workshop.

CO4: Familiarization of soldering and wiring.

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

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

Textbooks:

1. Ross, S. L., *Differential Equations*, 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).

Course Outcomes (COs):

CO1: Differentiate between pointwise and uniform convergence, check whether a given series is pointwise or uniformly convergent series, and apply the techniques to integral and differential calculus.

CO2: Analyze and solve ODEs, confirm existence and uniqueness of solutions of IVP. Find power series solution of linear homogeneous ODE with variable coefficients and Frobenius method for equations with regular singular point. Know the special functions like Legendre polynomial, Bessel function etc. and properties. Finding eigenvalues and eigenfunctions for Sturm-Liouville problems.

CO3: Verify continuty/differentiability of scalar/vector-valued function. Calculate line/surface integration of scalar/vector-valued functions. Apply fundamental theorems to understand the nature of vector fields and check if a given vector field is conservative.

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

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

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

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

Textbooks:

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

References:

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

Course Outcomes (COs):

CO1: Introduction to the tools of vector calculus and their applications in the formulation of electromagnetic theory via Maxwell's equations.

CO2: Familiarization with various techniques such as multipole expansions for solving problems in electrostatics and magnetostatics.

CO3: Introduction to electrodynamics and familiarization with its formulation in terms of tensors.

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

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*, 4^{th} ed., Thompson-Engineering (2006).

Course Outcomes (COs):

CO1: Understand the fundamental principles of materials science.

CO2: Appreciate the applications of different classes of materials in day today life as well as in strategic sectors.

CO3: Evaluate the properties of materials for and applying in different applications.

AV121 DATA STRUCTURES AND ALGORITHMS (3 – 1 – 0) 4 Credits

Time complexity analysis. Big-Oh, Big-Omega, and Big-Theta notations.

Data Types, ADTs, Various types of ADTs such as List, Set Ques, circular queue, trees, graphs etc. 2-3 tree, red-black trees, binary trees, search trees, n-ary trees.

Graph traversals, searching on graph, BFS, DFS, Spanning Tree, Minimum Spanning Tree, paths, shortest paths, TSP.

Data structures for maintaining ranges, intervals and disjoint sets with applications.

Binary heap, binomial and fibonacci heaps, skip lists, Hashing, universal hashing, integer sorting algorithms with analysis.

Algorithm design: greedy, divide and conquer, dynamic programming, branch and bound, randomized algorithms. Advanced data structures.

Textbooks/ References:

1. Gregory L. H., *Data Structure, Algorithm and OOP*, Tata Mc Graw Hill, New Delhi.
2. Adam D., *Data Structures & Algorithm in C++*, Vikas publication House.
3. Aho, Hopcroft, and Ulmann, Data Structures and Algorithms, Pearson 1982.
4. T. Cormen, C. Leiserson, R. Rivest, and C. Stein, Introduction to Algorithms, 3^{rd} ed., MIT Press, 2009.
5. Debasis Samanta, Classic Data Structures, Prentice Hall India Learning Private Limited, 2009.

Course Outcomes (COs):

CO1: Compare different programming methodologies and define asymptotic notations to analyze performance of algorithms.

CO2: Use appropriate data structures like arrays, linked list, stacks and queues to solve real world problems efficiently.

CO3: Represent and manipulate data using nonlinear data structures like trees and graphs to design algorithms for various applications.

CO4: Illustrate and compare various sorting and searching techniques including hashing.

AV122 BASIC ELECTRICAL AND ELECTRONICS ENGG. (3 – 1 – 0) 4 Credits

DC Circuit Analysis: Network Theorems - Thevenin's theorem, Norton's theorem, Superposition theorem, Maximum power transfer theorem.

AC Circuit Analysis: Basic concepts of AC circuits – RMS value and average value – Behavior of resistor, capacitor and inductor in AC circuits – Sinusoidal steady state analysis of AC circuits – Power – Power factor - Resonance in AC circuits.

Introduction To Magnetic Theory

Diode – clipping, clamping circuits, applications in rectifiers and power supplies. Amplifiers: BJT-Characteristics- DC analysis and AC analysis of BJT. Application of BJT as amplifiers/switch.

Introduction to operational amplifiers – characteristics/specifications and application circuits. 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*, 10^{th} ed., Pearson Education (2009).
2. Mano, M. M. and Ciletti, M. D., *Digital Design*, 4^{th} ed., Pearson Education (2002).
3. Same as Reference (Electrical Part)

References:

1. Vincent, D. T., *Electrical Engineering Fundamentals*, Pearson Education, 1989
2. A. E. Fitzgerald, David E. H., Arvin G., *Basic Electrical Engineering*, Tata McGraw-Hill, 2010.
3. Hughes, E., *Electrical and Electronic Technology*, Pearson Education, 2008.
4. Charles, K. A., Mathew, N. O. S., *Fundamentals of Electric Circuits*, McGraw-Hill; 4^{th} edition, 2008.
5. A. E. Fitzgerald, C. Kingsley, Jr., S. D. Umans, *Electric Machinery*, Tata Mcgraw-Hill, 2017.
6. M. G. Say, *Performance and Design of AC Machines*, CBS; 3^{rd} edition, 2002
7. Mittle, V. N. and Mittal, A., *Basic Electrical Engineering*, 2^{nd} ed., Tata McGraw Hill (2006).
8. Cotton, H., *Principles of Electrical Engineering*, Sir Isaac Pitman & Sons (1967).
9. Mottershed, A., *Electronic Devices and Circuits: An Introduction*, 12^{th} Indian ed., EEE Publication (1989).
10. Bapat, Y. N., *Electronic Devices and Circuits*, 9^{th} ed., Tata McGraw Hill (1989).
11. Malvino, A. P., *Electronic Principles*, 12^{th} ed., 3^{rd} TMH ed., Tata McGraw Hill (1989).
12. Jain, R. P., *Modern Digital Electronics*, McGraw Hill (2004).
13. Floyd, T. L., *Electronic Devices*, 8^{th} ed., Pearson Education (2007).

Course Outcomes (COs):
CO1: Demonstrate Proficiency in DC Circuit Analysis
CO2: Apply AC Circuit Analysis Techniques
CO3: Understanding of the characteristics of diodes and transistors
CO4: Understanding of the operational circuits and its design
CO5: Realize digital circuits using basic gates

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.

Textbooks:

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

References:

1. Jolhe, D. A., *Engineering Drawing with an Introduction to AutoCAD*, Tata McGraw Hill (2008).
2. Venugopal, K. and Prabhu Raja, V., *Engineering Drawing + AutoCAD*, 5th ed., New Age International (2011).
3. Varghese, P. I., *Engineering Graphics with AutoCAD*, 26th ed., VIP Publishers (2012).
4. Luzadder, W. J. and Duff, J. M., *Fundamentals of Engineering Drawing*, 11th ed., Pearson Education (2015).
5. Bethune, J. D., *Engineering Graphics with AutoCAD 2014*, Pearson Education (2014).

Course Outcomes (COs):

CO1: Read and interpret engineering drawings.
CO2: Creating orthographic, and isometric views.
CO3: Improving visualization skills.
CO4: Use CAD software for creating drawings and concepts.

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.

Course Outcomes (COs):

CO1: Understand to handle instruments in electrochemistry experiments.
CO2: Analyze techniques for characterization of different classes of materials.
CO3: Analyze the results from the experiments and draw conclusions.

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 Cauchy's 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*, 10^{th} 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*, 9^{th} 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*, 4^{th} ed., Alpha Science Intl. Ltd. (2013).

Course Outcomes (COs):

CO1: Understand the basic concepts of vector space and subspaces
CO2: Determine rank and nullity of space and matrix of linear Transformation
CO3: Understand basic concepts of analytic functions and harmonic functions
CO4: Evaluate integrals of features using Cauchy's theorem and Cauchy integral formula
CO5: Apply Taylor's and Laurent's series expansion and find singularities of function
CO6: Understand the convergence of Fourier series and evaluate Fourier series of periodic and even functions

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

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

Textbooks:

- 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).

Course Outcomes (COs):

CO1: To make the student gain familiarity with thermodynamic system, assess and evaluate heat and work type energy interaction for various closed thermal systems using first law, handle the behaviour of a simple, pure substance including solid-liquid and gas phases.

CO2: To teach students to evaluate mass and energy conservation of control volumes and compute state changes, heat and work interactions and also handle simple transient situations.

CO3: To teach computation of entropy changes and make process evaluation using combined first and second law and compute the increase of entropy for various physical systems.

CO4: To make students familiar with various gas power cycles, vapor power cycles, and refrigeration and carry out simple thermodynamic evaluation.

CO5: To make students do simple exergy analysis and evaluate the thermodynamic efficacy of various processes.

AE212 — MECHANICS OF SOLIDS — (3 – 0 – 0) 3 Credits

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

Textbooks:

- 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).

Course Outcomes (COs):

CO1: Draw free body diagrams and set up equilibrium equations.

CO2: To understand the concept of stress and strain, and their relationship.

CO3: To determine principal stresses and angles, maximum shearing stresses and angles, and the stresses acting on any arbitrary plane within a structural element.

CO4: To calculate forces, deflection, moments, stresses and strain of structural members.

CO5: Apply failure criteria on fundamental elements of engineering structures.

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.

Textbooks:

1. Cengel, Y. A. and Cimbala, J. M., *Fluid Mechanics: Fundamentals and Applications*, 4^{th} ed., McGraw-Hill (2019).

References:

1. Fox, R. W., McDonald, A. T., Pritchard, P. J., and Mitchell, J. W., *Fluid Mechanics*, John Wiley (2018).
2. Munson, B. R., Okiishi, T. H., Huebsch, W. W., and Rothmayer, A. P., *Fundamentals of Fluid Mechanics*, 7^{th} ed., Wiley (2017).
3. White, F. M. and Xue, H., *Fluid Mechanics*, 9^{th} ed., McGraw-Hill (2022).
4. Kundu, P. K., Cohen, I. M., and Dowling, D. R., *Fluid Mechanics*, 6^{th} ed., Academic Press (2015).
5. Massey, B. S. and J. Ward-Smith, *Mechanics of Fluids*, 7^{th} ed., Nelson Thornes (1998).
6. Potter, M. C., Wiggert, D. C., and Ramadan, B. H., *Mechanics of Fluids*, 5^{th} ed., Cengage (2017).
7. Wilcox, D. C., *Basic Fluid Mechanics*, 5^{th} ed., DCW Industries (2013).

Course Outcomes (COs):

CO1: Know the fundamental concepts of fluid mechanics such as continuum, fluid properties, velocity field; classification of fluid flows.

CO2: Apply the hydrostatic equation to determine forces on submerged surfaces; to manometers for pressure measurements; to the determination of buoyancy and stability; and to fluids undergoing rigid-body motion.

CO3: Use of finite control volume formulation of conservation laws and apply them to determine gross parameters in a fluid flow system. Understand the concepts of static, dynamic, and stagnation pressures. Use of Bernoulli equation in flow problems.

CO4: Use differential forms of conservation laws and apply them to determine velocities, pressures and acceleration in a moving fluid. Understand the kinematics of fluid particles, including the concepts of substantial acceleration, deformation, rotation, vorticity, and circulation.

CO5:Use of analytical solutions of simple incompressible laminar flow systems. Use of Dimensional analysis. Determine flow rates, pressure changes, minor and major head losses for incompressible viscous flows through pipes.

CO6:Use of concepts in potential flows to analyse elementary flow patterns (source, sink, vortex flows, and superposition of these flows) in an ideal fluid flow.

CO7:Understand the concepts of incompressible boundary layers and use the momentum integral equation to determine boundary layer thicknesses, wall shear stresses, and skin friction coefficients.

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*, 5^{th} 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*, 4^{th} 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*, 5^{th} ed., Wiley-India (2012)

Course Outcomes (COs):

CO1: Discuss the fundamentals of theoretical/practical aspects in machining (Material removal) techniques that find extensive use in various mechanical/aerospace applications

CO2: Implement the above knowledge (a) for reasoning and problem-solving related to machining science and technology and (b) to comprehend industrial practices including CNC machining, non-traditional machining, etc.

CO3: Differentiate various terminologies/ methodologies /practices associated with machining techniques, to have an assessment of their suitability in end-use applications.

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

References:

1. Gardner, A., *Macroeconomic Theory*, Surjeet Publications (1998).
2. Koutsoyiannis, A., *Modern Microeconomics*, 2^{nd} 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*, 7^{th} ed., Oxford Univ. Press (2005).
5. Todaro, M. P. and Smith, S. C., *Economic Development*, 8^{th} ed., Pearson Education Ltd. (2008).
6. Economic Survey 2008, Government of India, Ministry of Finance.
7. O'Connor, D. E., *The Basics of Economics*, Greenwood Press (2004).

Course Outcomes (COs):

CO1: Better Development of Technology - Students will be able to explain the basic economics concepts and should be able to understand economic problems for better development of technology.

CO2: Helps in Engineering Decisions - The course will help to develop theoretical and analytical skills of the students so that they can make firm level decisions using various principles of economics.

CO3: Equip to handle the dynamics of production and business - It will equip students with the capability to understand and handle the dynamics of economics and business of the changing world economy.

CO4: Solving economic problems through engineering solutions - Students will be able to connect/ use their engineering and scientific knowledge for solving economic problems and development challenges of the country.

CO5: Better understanding of real-life problems and technology solutions - By understanding the strengths and weaknesses of the economy, the students will be able to sensitize about real life issues and can become better engineers and scientists.

AE231 **STRENGTH OF MATERIALS LAB** (0 – 0 – 3) 1 Credit

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

Course Outcomes (COs):

CO1: To verify, understand and apply the material testing concepts students have learned by conducting simple experiments using benchmark experimental setups.

CO2: To analyse the results obtained and independently come to conclusions, and develop report writing skills.

CO3: To develop simple experimental setups/procedures using available resources on their own, conduct experiments & analyse results.

AE232 MACHINE DRAWING (0 – 0 – 3) 1 Credit

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).

Course Outcomes (COs):

CO1: Understand the orthographic projections including sectional views of components/ assembly.

CO2: Identify the parts/ components, and create 2D drawing of parts and assembly of mechanical assemblies using AutoCAD.

CO3: Create 3D models of parts, and assembly of mechanical subassemblies/ assemblies.

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 in- tegrals – 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*, 10$^{\text{th}}$ 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*, 3$^{\text{rd}}$ 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*, 2$^{\text{nd}}$ ed., Springer-Verlag (2004).
6. McOwen, R. C., *Partial Differential Equations: Methods and Applications*, 2$^{\text{nd}}$ ed., Pearson Education (2003).
7. Borelli, R. L., *Differential Equations: A Modelling Perspective*, 2$^{\text{nd}}$ ed., Wiley (2004).

Course Outcomes (COs):

CO1: Evaluate and Understand Fourier Transforms and Laplace Transforms.

CO2: Understanding Linear First order Partial Differential Equations and second order PDE.

CO3: Evaluate problems using Charpits method, PDEs using separation of variables, second order PDE with constant and variable coefficient.

CO4: Understand the concept of maxima and minima of functionals and Isoperimetric problems.

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*, 5^{th} ed., McGraw Hill (2010).

References:

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

Course Outcomes (COs):

CO1: Identify and formulate the correct set of assumptions and boundary conditions for aerodynamic force calculations for incompressible flow.

CO2: Apply analytical methods based on potential flow theory to estimate the aerodynamic force on finite wings in incompressible flow.

CO3: Develop numerical algorithms based on panel methods for aerodynamic analysis of simple configurations.

CO4: Use boundary layer theory to estimate viscous drag on simple configurations and apply corrections to potential flow based methods.

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*, 7^{th} ed., John Wiley (2011).

Data Book:

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

References:

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

Course Outcomes (COs):

CO1: Importance of the heat transfer mechanism and its basic laws.
CO2: Understand and solve the steady state heat conduction.
CO3: Learn and analyse the transient heat conduction.
CO4: Need and importance of external and internal convective heat transfer processes.
CO5: Estimation of heat transfer coefficients of buoyancy assisted convection operations.
CO6: Evaluation of thermal performance of Heat exchangers.
CO7: Calculate the radiation heat transfer between black body surfaces.

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).

Course Outcomes (COs):

CO1: Perform kinematic analysis of particles/ rigid bodies.
CO2: Perform dynamic analysis of rigid bodies using various methods.
CO3: Formulate and solve equations of motion for single degree of freedom vibration systems under free and forced conditions.

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).

Course Outcomes (COs):

CO1: Discuss the fundamentals of theoretical/practical aspects in machining (Material removal) techniques that find extensive use in various mechanical/aerospace applications

CO2: Implement the above knowledge (a) for reasoning and problem-solving related to machining science and technology and (b) to comprehend industrial practices including CNC machining, non-traditional machining, etc.

CO3: Differentiate various terminologies/ methodologies /practices associated with machining techniques, to have an assessment of their suitability in end-use applications.

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).

Course Outcomes (COs):

CO1: Holistic understanding about society and awareness of humanitarian and social issues.
CO2: Application of the sciences for the improvement of the quality of life.
CO3: Enhancing the analytical capabilities of students and cultivate critical thinking.
CO4: Understand ethics and values of life and its application in professional and personal life.

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.

Course Outcomes (COs):

CO1: To enable the student to perform test and evaluate the performance of IC engines, Blowers and simple thermal engineering units like refrigeration units.

CO2: To enable the student to evaluate the heat transfer under steady state laboratory conditions by tests in simple units involving conduction, convection and radiation.

CO3: To enable the student to characterize flow measuring devices, characterize performance of fluid machines and assess flow losses by simple pipe flow test.

CO4: To equip the student with the capability of demarcating various errors and uncertainties in their measurements and proper quantify the same.

AE242 METROLOGY AND COMPUTER AIDED INSPECTION LAB (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*, 5^{th} 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*, 2^{nd} ed., Delmar Pub. (1988).

Course Outcomes (COs):

CO1: Familiarization and hands-on exercises on traditional industrial measuring practices, measuring systems/ metrology instruments.

CO2: Familiarization of dimensional and geometric tolerances, assembly fits, surface roughness, etc., and their measurements.

CO3: Implementation of above knowledge for solving typical tasks/ questions in metrology and to have an assessment of suitable measurement techniques for end-use applications.

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).

Course Outcomes (COs):

CO1: Learn fundamental concepts of probability, statistics and numerical methods in detail to enable students to identify the relevance of these concepts and apply them in the modelling and performance analysis of several electronics and communication systems.

CO2: Understand random variables and their probability distributions chosen to model various random phenomena arising in models of systems.

CO3: Analyse sampling theory to understand the information in a sample to estimate system parameters.

CO4: Understand various standard numerical techniques to apply them appropriately in the modelling and analysis of several engineering systems.

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

Governing equations – quasi-one-dimensional flows – acoustic waves and waves of finite ampli- tude – 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 Gas Dynamics*, 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).

Course Outcomes (COs):

CO1: Ability to analyse simple 1D/2D inviscid compressible flow with shock waves.

CO2: Analyse Quasi 1D gas dynamic problems applied to supersonic nozzles and wind tunnels.

CO3: Apply Fanno and Rayleigh flow theory for preliminary analysis of compressible flow in ducts.

CO4: Use MOC to solve 2D, isentropic compressible flows.

CO5: Estimate/Derive aerodynamic coefficients for simple geometries for compressible flow

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).

Course Outcomes (COs):

CO1: Formulate the equations of motion for aircraft in various flight phases under equilibrium conditions with appropriate assumptions.

CO2: Define and derive the performance and stability attributes of aircraft in terms of the design variables for both jet and propeller propulsion units.

CO3: Develop the competency to evaluate out the performance and stability characteristics of any given aircraft.

CO4: Identify and evaluate the aircraft design parameters.

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, bielliptic 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).

Course Outcomes (COs):

CO1: Apply the basic conservation laws and concepts of orbital mechanics for problem solving.

CO2: Design, evaluate and select required orbits for spacecrafts around earth.

CO3: Evaluate and determine suitable orbital transfers needed for space mission design.

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).

Course Outcomes (COs):

CO1: Develop rigorous concepts of deformation , stress and strain with elegant representation.

CO2: Formulate boundary value problems in elasticity and grasp the various solution methodologies.

CO3: Interpret the elastic analysis results for design, problem solving and research purposes of engineering structures.

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).

Course Outcomes (COs):

CO1: Develop transfer function model of LTI systems.

CO2: Compute and analyse the transient behaviour and steady state characteristics from the mathematical model.

CO3: Assess the stability of LTI systems.

CO4: Design simple controllers like PID and lag-lead compensators for LTI systems.

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.

Course Outcomes (COs):

CO1: Explain the design principles of wind tunnels and relevant flow diagnostic techniques.
CO2: Evaluate and select appropriate experimental techniques to understand the flow physics.
CO3: Collaborative with colleagues to perform experiments in low speed wind tunnels.
CO4: Post processing and analyzing of experimental data.
CO5: Collaborative with colleagues to disseminate the findings in the form of reports and presentations.

AE332 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

Course Outcomes (COs):

CO1:
CO2:
CO3:
CO4:

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., *Aircraft 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).

Course Outcomes (COs):

CO1: To enable the student to perform thermodynamic cycle analysis of air breathing engines and assess their capability.

CO2: Understand configuration of various engines and perform real analysis considering the performance indicators and efficiencies of various engine components.

CO3: Introduce handling flow analysis through aero-turbomachines using velocity triangles.

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).

Course Outcomes (COs):
CO1: Students should be able to use mathematical and physical knowledge to undertake stress and deformation analysis of the basic structural components such as Thin Plates.
CO2: Students should be able to use mathematical and physical knowledge to undertake stress and deformation analysis of the basic structural component such as Thin walled Beams.
CO3: Understand how composite materials differ from isotropic materials & analyse composite materials.
CO4: Students should be able to analyse a typical aerospace component using an FEM software.

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).

Course Outcomes (COs):
CO1: Understand the scope, objectives, and functions of management in theoretical and practical settings.

CO2: Understand the roles and apply the skills needed by a manager to do the jobs efficiently and effectively.

CO3: Apply CPM and PERT techniques for planning, scheduling and controlling of projects.

CO4: Apply quantitative techniques in management to solve real-world problems for improved decision-making.

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

- Refer list of electives

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

- Refer list of electives

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

- Refer list of electives

AE341 **AEROSPACE STRUCTURES LAB** (0 – 0 – 3) 1 Credit

Buckling of struts 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.

Course Outcomes (COs):

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

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

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

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.

Course Outcomes (COs):

CO1: Familiarization of CNC Programming/ Manufacturing Simulation.

CO2: Familiarization/ Hands on exercises on CNC systems/ non-traditional machining/ metal forming/ welding etc.

CO3: Implementation of above knowledge for solving typical manufacturing tasks/ assignments and preparation of appropriate reports.

SEMESTER VII

AE411 **ROCKET PROPULSION** (3 – 0 – 0) 3 Credits

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

Textbook:

- Sutton, G. P. and Biblarz, O., *Rocket Propulsion Elements*, 7$^{\text{th}}$ ed., John Wiley (2000).

References:

1. Hill, P. G. and Peterson, C. R., *Mechanics and Thermodynamics of Propulsion*, 2$^{\text{nd}}$ ed., Pearson Education (2009).
2. Ramamurthi, K., *Rocket Propulsion*, Macmillan (2010).

Course Outcomes (COs):
CO1: Knowledge about the different types of rocket propulsion systems.
CO2: Knowledge about the different parameters that influence the performance of chemical rockets.
CO3: Obtain detailed knowledge about the different components and working of the chemical rocket propulsion systems.
CO4: Obtain knowledge about the different types of propellants used for chemical propulsion and the factors affecting their performance.
CO5: Knowledge about the processes and criteria followed in the selection of propulsion system for a mission.
CO6: Knowledgeable about contemporary research in rocket propulsion related disciplines.
CO7: Ability to disseminate knowledge in rocket propulsion research through presentation of scientific talks.

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*, 2^{nd} ed., Adaso/Adastra Engineering Center (1999).

Course Outcomes (COs):

CO1: Capable of developing conceptual/preliminary design of aerospace vehicles such as Launch vehicles, Spacecraft and Aircraft.

CO2: Develop the ability to use fundamental engineering principles of flight mechanics, aerodynamics, propulsion, thermal science, structures, and other related areas in Launch vehicle/spacecraft/aircraft design.

CO3: Explore and analyse alternative design options through trade studies to efficiently achieve design objectives of aerospace vehicles for a mission mode.

CO4: Learn to participate and contribute effectively as a responsible team player in multidisciplinary design teams and cross-disciplinary.

AE413 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*, 2^{nd} ed., Wiley-India (2006).
2. Rao, S. S., *Engineering Optimization: Theory and Practices*, 4^{th} ed., John Wiley (2009).

References:

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

Course Outcomes (COs):

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

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

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

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

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).

Course Outcomes (COs):

CO1: Understand biological, physical, and industrial processes relevant to environmental problems.

CO2: Understand the causes and effects of environmental problems, and explain engineering solutions.

CO3: Apply their knowledge of environmental science and engineering to specific scenarios or problems and analyze case studies related to environmental challenges, design sustainable engineering solutions, or implement eco-friendly practices within their organizations/society.

CO4: Analyse the ethical reflection regarding environmental problems in local, regional, national, and global communities and the importance of systemic study and evaluation of the environment during any initiative or plans.

CO5: Enable to make judgments and critique the effectiveness of environmental policies, strategies, and solutions.

CO6: Enable to nurture knowledge, respect, and protect the environmental resources and design solutions in the realm of environmental science and engineering.

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

- Refer list of electives

E05 **INSTITUTE ELECTIVE** (2/3 – 0 – 0) 2/3 Credits

- Refer list of electives

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.

Course Outcomes (COs):

CO1:

CO2:

CO3:

CO4:

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

Course Outcomes (COs):

CO1: Basic understanding for analysing LTI systems using MATLAB and SIMULINK.

CO2: Experience in writing numerical integration programs in MATLAB for closed loop control systems using electromechanical actuators.

CO3: Ability to perform mathematical modelling and simulation of practical nonlinearities such as stiction, coulomb friction, current loop with power amplifier saturation, nonlinear flow gain characteristics of hydraulic servo valves etc.

CO4: Experience in mathematical modelling, analysis, and compensator design of electromechanical actuation systems used in launch vehicles.

CO5: Experience in mathematical modelling and analysis of electrohydraulic actuation systems used in launch vehicles.

CO6: Experience in coding frequency response program for nonlinear dynamical systems in MATLAB.

CO7: Familiarity with the sensor hardware characterization experiments.

AE432 **SUMMER INTERNSHIP AND TRAINING** 3 Credits

SEMESTER VIII

AE441 **COMPREHENSIVE VIVA-VOCE** 3 Credits

AE442 **PROJECT WORK** 12 Credits

Electives

AE447 MULTI-RIGID BODY DYNAMICS (3 – 0 – 0) 3 Credits

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

References:

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

Course Outcomes (COs):

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

AE448 ANALYTICAL METHODS IN THERMAL AND FLUID SCIENCE (3 – 0 – 0) 3 Credits

Special Functions, Bessel equation and related functions, Laplace transform methods: Inverse Laplace transform, Complex numbers, Bromwich integral, bilateral Laplace transforms, solution to ordinary and partial differential equation, Green function and boundary value problems, Fourier transform methods, Mellin transforms. Eigenvalue problems and Eigen function expansions: Sturm-Liouville problems. Integral equations, Perturbation methods.

References:

1. Herron, I. H. and Foster, M. R., *Partial Differential Equations in Fluid Dynamics*, Cambridge Univ. Press (2008).
2. Telionis, D. P., *Unsteady Viscous Flows*, Springer (2012).
3. Duffy, D. G., *Advanced Engineering Mathematics with MATLAB*, 4rd ed., CRC Press (2016).
4. Greenberg, M. *Advanced Engineering Mathematics*, rd ed., Pearson Education (2002).
5. Myers, G. E., *Analytical Methods in Conduction Heat Transfer*, 2nd ed., Amch (1998).
6. Weigand, B., *Analytical Methods for Heat Transfer and Fluid Flow Problems*, 2nd ed., Springer (2015).

7. Arfken, G. B., Weber, H. J., and Harris, F. E., *Mathematical Methods for Physicists,*, 7rd ed., Academic Press (2012).

AE449 ROBOT MECHANISMS AND TECHNOLOGY (3 – 0 – 0) 3 Credits

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

References:

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

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

AE450 OPTICAL AND LASER BASED COMBUSTION DIAGNOSTICS (3 – 0 – 0) 3 Credits

Role of Optical Diagnostic Techniques in Combustion Studies – Planar Imaging Systems (Lasers, Camera, Optics, Signal and Noise) – Optical Diagnostics (Shadowgraphy, Schlieren, Luminosity, Chemiluminescence) – Scattering Processes (Elastic, Inelastic) – Laser Diagnostics (Background Physics, Absorption, LIF, Rayleigh, Raman, CARS, LII, PIV, LDV, PDPA) – High speed Diagnostics – Simultaneous Diagnostics – Safety Procedures.

References:

1. Eckbreth, A. C., *Laser Diagnostics for Combustion Temperature and Species*, CRC Press (1996).
2. Hanson, R. K., Spearrin, R. M., and Goldenstein, C. S. (Eds.), *Spectroscopy and Optical Diagnostics for Gases*, Springer (2016).
3. Atkins, P. and de Paula, J., *Physical Chemistry*, 11th ed., Oxford Univ. Press (2018).
4. Franz Mayinger, F. and Feldmann, O., *Optical Measurements: Techniques and Applications*, 2nd ed., Springer (2001).

Course Outcomes (COs):
CO1: The student should be able to decide on the kind of optical or laser based diagnostic methodology that needs to be implemented for the investigation of the combustion system of interest.

CO2: The student will be having awareness in deciding the different components and specification of the laser diagnostic system required.

CO3: The student will be able to better understand and appreciate peer reviewed literature/reports where optical and laser diagnostic methods are used for investigations.

CO4: The student should be able to write scientific reports with good analysis of the experimental data and discuss on the limitations of the methods used.

AE451 PHYSIOLOGICAL FLUID MECHANICS (3 – 0 – 0) 3 Credits

Introduction to Physiological Fluid Mechanics; Review of Concepts in Fluid Mechanics, Kinematics, Hydrostatics, Conservation relations, Viscous Flow, Unsteady Flow; Clinical Fluid Dynamic Measurements; Analysis of Total Peripheral Flow; Circulatory Biofluid Mechanics, Blood Rheology, Blood Composition and Structure, Flow Properties of Blood, Blood Vessel Structure; Models of Biofluid Flow, Models of Blood Flow, Applications of Poiseuilli's Law for the study of Blood Flow; Introduction to Non-Newtonian Fluids, Power Law Model, Herschel-Bulkley Model, Casson Model, Non-Newtonian Flow in Elastic Tubes; Introduction to Heart Mechanics, Cardiac Geometry, Materials, and Electric System, Mechanical Cycle Events & Vent. Function Curve, Operation of Heart Valves, Blood Flow in Arteries, Shear Stress on Vessel Wall, Blood Vessel Bifurcation, Bifurcation Patterns, Uniform Shear Hypothesis.

Textbooks:

1. Mazumdar, J., *Biofluid Mechanics*, 2^{nd} ed., World Scientific (2016).
2. Fung, Y. C., *Biomechanics: Circulation*, 2^{nd} ed., Springer (1997).

References:

1. Ross Ethier, C. and Simmons, C. A., *Introductory Biomechanics*, Cambridge University Press (2007).
2. Kleinstreuer, C., *Biofluid Dynamics: Principles and Selected Applications*, CRC Press (2006).
3. Zamir, M., *The Physics of Pulsatile Flow*, Springer (2000).
4. Waite, L. and Fine, J., *Applied Biofluid Mechanics*, McGraw Hill (2007).
5. Waite, L., *Biofluid Mechanics in Cardiovascular Systems*, rd ed., McGraw Hill (2006).

AE452 RANDOM VIBRATIONS AND APPLICATIONS (3 – 0 – 0) 3 Credits

AE453 ROTORDYNAMICS (3 – 0 – 0) 3 Credits

AE454 EXPERIMENTAL MODAL ANALYSIS (3 – 0 – 0) 3 Credits

AE455 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 (Von Mises and Tresca), octahedral shear stress and shear strain, stress invariants, Deformation work and power, Plastic stress - strain relations, Fundamentals of metal forming - Extrusion, rolling, wire drawing, Forging, Friction and lubrication in metal forming processes, Mechanics of meal working by slab method, Tension testing.

Textbook:

- Dieter, G. E., *Mechanical Metallurgy*, 3rd ed., McGraw Hill (2017).

References:

1. Courtney, T., *Mechanical Behaviour of materials*, 2nd ed., Waveland Press (2005).
2. Sluzalec, A., *Theory of Metal Forming Plasticity: Classical and Advanced Topics*, Springer (2004).
3. Chakrabarty, J., *Theory of Plasticity*, 3rd ed., Elsevier (2007).
4. Singh, S., *Theory of Plasticity and Metal Forming Processes*, Khanna Publishers (2008).

AE456 **NUMERICAL METHODS FOR SCIENTIFIC COMPUTING** (3 – 0 – 0) 3 Credits

Mathematical review and computer arithmetic – 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, trigonometric approximation, rational approximation, wavelet bases; Numerical differentiation; Numerical integration – Romberg integration, Gauss quadrature, 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. Trangenstein, J. A., *Scientific Computing: Vol. I - Linear and Nonlinear Equations*, Springer (2017).
2. Trangenstein, J. A., *Scientific Computing: Vol. II - Eigenvalues and Optimization*, Springer (2017).
3. Trangenstein, J. A., *Scientific Computing: Vol. III - Approximation and Integration*, Springer (2017).
4. Moin, P., *Fundamentals of Engineering Numerical Analysis*, Cambridge Univ. Press (2010).
5. Chapra, S. C., *Applied Numerical Methods with MATLAB for Engineers and Scientists*, 3rd ed., (2011).
6. Gander, W., Gander, M. J., and Kwok, F., *Scientific Computing: An Introduction using Maple and MATLAB*, Springer (2014).
7. Ackleh, A. S., Allen, E. J., Hearfott, R. B., and Seshaiyer, P., *Classical and Modern Numerical Analysis: Theory, Methods and Practice*, CRC Press (2009).
8. Gilat, A. and Subramaniam, V., *Numerical Methods for Engineers and Scientists: An Introduction with Applications Using MATLAB*, 3rd ed., (2013).

AE457 FLIGHT DYNAMICS AND CONTROL (3 – 0 – 0) 3 Credits

Equations of Motion: rigid body dynamics, coordinate transformation, Euler angle & quaternion formulation – Dynamics of Generic Fixed Wing Aircraft: 6-DoF equations of motion, linearized equations of motion, linearised longitudinal & lateral equations, aerodynamic derivatives – LTI system basics – Stability of Uncontrolled Motion: linearized longitudinal & lateral dynamics, modes of motion – Response to Control Inputs: transfer function, step response & frequency response characteristics – Feedback Control: stability augmentation, PID control, root-locus technique for controller design – Introduction to modern control theory.

References:

1. Etkin, B. and Reid, L. D., *Dynamics of Flight: Stability and Control*, 3rd ed., Wiley (1996).
2. Phillips, W. F., *Mechanics of Flight*, 2nd ed., John Wiley (2009).
3. Nelson, R. C., *Flight Stability and Automatic Control*, 2nd ed., Tata McGraw Hill (1997).
4. Cook, M., *Flight Dynamics Principles: A Linear Systems Approach to Aircraft Stability and Control*, 3rd ed., Elsevier (2012).
5. Stevens, B. L. and Lewis, F. L., *Aircraft Control and Simulation*, 2nd ed., Wiley (2003).
6. Stengel, R. F., *Flight Dynamics*, Princeton Univ. Press (2004).

Course Outcomes (COs):

CO1: Formulate the 6 DOF nonlinear and linearized equations of a conventional aircraft in flight about the equlibrium states.

CO2: Develop the competency to infer the stability and control derivatives of any given aircraft.

CO3: Deduce and analyze the longitudinal and lateral-directional modes.

CO4: Assess the handling qualities of a conventional aircraft.

CO5: Derive the transfer functions for aircraft motion for different control inputs.

CO6: Implement stability augmentation system and Autopilot for a conventional aircraft the using classical and modern control techniques.

AE458 STRUCTURAL ACOUSTICS AND NOISE CONTROL (3 – 0 – 0) 3 Credits

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

References:

1. Munjal, M. L., *Noise and Vibration Control*, World Scientific Press (2013).
2. Williams, E. G., *Fourier Acoustics: Sound Radiation and Nearfield Acoustic Holography*, Academic Press (1999).
3. Kinsler, L. E., Frey, A. R., Coppens, A. B., and Sanders, J. V., *Fundamentals of Acoustics*, 4^{th} ed., Wiley (2000).

Course Outcomes (COs):

CO1: Understand fundamentals of acoustic wave propagation.

CO2: Understand different acoustic sources and it's properties.
CO3: Understand and design Mufflers and Horns.
CO4: To know basic noise control measures.

AE459 MACHINE DESIGN (2 – 0 – 1) 3 Credits

Design process: identification of needs and requirements, conceptual solutions, preliminary design,detailing, manufacturing considerations, prototyping and testing.

Machine elements selection/design: shafts, couplings, pulleys and cables, clutches, screws, gears, cams, springs, structural elements, structural joints, sliding contact bearings, lubrication, rolling element bearings.

References:

1. Norton, R. L., *Machine Design - an Integrated Approach*, Pearson, 5th ed., 2013
2. Slocum, A. H., *Precision Machine Design*, Society of Manufacturing, 1992
3. Bhandari, V. B., *Design of Machine Elements*, Tata McGrahill, 3rd ed., 2010
4. Shigley, J., Mischke, C., and Brown, T. H., *Standard Handbook of Machine Design*, 3rd ed., 2004

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*, 8^{th} 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*, 5^{th} 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*, 3^{rd} 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).

AE465 ADVANCED PROPULSION SYSTEMS (3 – 0 – 0) 3 Credits

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

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

References:

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

AE471 **CONVECTIVE 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).

Course Outcomes (COs):

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

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

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

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

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 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:

- Lyall, F. and Larsen, P. B., *Space Law: A Treatise*, 2nd ed., Routledge (2017).
- Diederiks-Verschoor, I. H. Ph. and Kopal, V., *An Introduction To Space Law*, 3rd ed., Kluwer Law International (2008).
- Mani, V. S., Bhatt, S., and Balakista Reddy, V., *Recent Trends in International Space Law and Policy*, 2nd ed., Asia Law House (2015).

References:

1. Von der Dunk, F., *Handbook of Space Law*, Edward Elgar Pub. (2017).
2. Venkata Rao, R., Gopalakrishnan, V., and Abhijeet, K. (Edts), *Recent Developments in Space Law: Opportunities & Challenges*, Springer (2018).
3. Nikam, R. J., Zwaan, T. M., and Balakista Reddy, V., *Space Activities and IPR Protection*, Asia Law House (2013).

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).

Course Outcomes (COs):

CO1: Identify the elements of operations management and the various transformation processes to enhance industrial productivity and competitiveness.

CO2: Prepare demand forecasts, aggregate production plans, master production schedule and materials requirement plans.

CO3: Analyze and solve facility planning problems, sequencing and scheduling problems in various manufacturing environments, and balancing of production line in a flow manufacturing environment.

CO4: Apply suitable inventory control techniques for materials management and quality control measures for total quality management.

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*, 2$^{\text{nd}}$ ed., McGraw Hill (2000).

References:

1. Glassman, I. and Yetter, R. A., *Combustion*, 4$^{\text{th}}$ ed., Academic Press (2008).
2. Kuo, K. K., *Principles of Combustion*, 2$^{\text{nd}}$ ed., John Wiley (2005).
3. Warnatz, J., Maas, U., and Dibble, R. W., *Combustion* 4$^{\text{th}}$ 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*, 3$^{\text{rd}}$ 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).

Course Outcomes (COs):

CO1: Apply relevant approximations in governing equations suitable for a particular problem to understand the flow physics.

CO2: Apply concepts from the boundary layer theory to compute and /or understand the drag and heat transfer in laminar flows.

CO3: Apply concepts from the statistical description of turbulence to understand the flow characteristics.

CO4: Able to compute numerical solutions for boundary layer equations.

CO5: Analyse the results from analytical and numerical solutions and disseminate the findings in the form of reports.

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).

Course Outcomes (COs):

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

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

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

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

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).

Course Outcomes (COs):

CO1: Develop thermodynamic models for simple equilibrium and non equilibrium reacting gas mixtures.

CO2: Analyse 1D/Quasi 1D gas dynamic problems using equilibrium and simple thermo-chemical non-equilibrium air models.

CO3: Solve simple practically relevant high temperature equilibrium/non-equilibrium flows using appropriate scientific computing tools.

CO4: Devise methods for generating high enthalpy flows using ground test facilities for hypersonic flow simulation.

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 – multiscale modeling and simulation methods – deformation and dynamical failure of brittle and ductile materials – applications.

References:

1. Buehler, M. J., *Atomistic Modeling of Materials Failure*, Springer (2008).
2. 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*, 2nd ed., Oxford Univ. Press (1985).

References:

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

AE487 **TURBOMACHINES** (3 – 0 – 0) 3 Credits

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).

Course Outcomes (COs):

CO1: To be thorough with thermodynamic performance of diffusers, compressors, turbines, nozzles along with Euler turbine equation.

CO2: To study the performance of axial compressors with velocity triangle and dimensional analysis.

CO3: To design and analyse axial compressors based on Degree of reaction, Stability margin, Cascade analysis, and by following different vortex theories.

CO4: To know the importance of radial compressors.

CO5: To construct velocity triangles of radial compressor at different reactions.

CO6: To understand the performance of radial compressor based on non-dimensional analysis and stability.

CO7: To be familiar with velocity triangles of axial/ radial turbines as well as their difference from the compressors.

CO8: To know the different types of turbines based on reaction and their design.

AE488 **ADVANCED MANUFACTURING AND AUTOMATION** (3 – 0 – 0) 3 Credits

Introduction to Turbomachines. Dimensional Analyses and Performance Laws.

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

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

Textbooks:

1. Groover, M. P., *Automation, Production Systems, and Computer-Integrated Manufacturing*, 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 HUMAN BEHAVIOUR IN ORGANIZATIONS (3 – 0 – 0) 3 Credits

Introduction - foundations of individual behavior and processes: personality, perception, workplace 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. Robbins, S. P. and Judge, T. A., *Organizational Behaviour*, 16th ed., Pearson Education (2015).
2. Greenberg, J. and Barron, R. A., *Behaviour in Organizations*, 10th ed., Prentice Hall (2012).
3. McShane, S. and Mary Von Glinow *Organizational Behaviour*, 7th ed., McGraw Hill (2014).
4. Newstrom, J. W. and Davis, K., *Organizational Behavior: Human Behavior at Work*, 11th ed., McGraw Hill (2001).

AE492 HYPERSONIC AERОTHERMODYNAMICS (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 effects: 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*, 2^{nd} ed., Taylor & Francis (1997).
3. Collier, J. G. and Thome, J. R., *Convective Boiling and Condensation*, 3^{rd} 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*, 2^{nd} 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).
6. Lesieur, M., *Turbulence in Fluids*, 2nd ed., Springer (2008).
7. Monin, A. S. and Yaglom, A. M., *Statistical Fluid Mechanics*, Dover (2007).
8. McComb, W. D., *The Physics of Fluid Turbulence*, Oxford Univ. Press (1992).

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 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., CUP (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).
5. Forrester, A., Sobester, A., and Keane, A., *Engineering Design via Surrogate Modelling: A Practical Guide*, Wiley (2008).

Course Outcomes (COs):
CO1: Convert complex design requirements to an optimisation problem statement.
CO2: Apply and analyse gradient and non-gradient optimisation algorithms for problem solution.
CO3: Create surrogate models to replace expensive analysis modules.
CO4: Solve optimisation problems under uncertainty.
CO5: Solve multi-objective optimisation problems.

AE497 ENERGY METHODS IN ENGINEERING (3 – 0 – 0) 3 Credits

AE498 COMPUTATIONAL METHODS FOR COMPRESSIBLE FLOWS (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).

Course Outcomes (COs):

CO1: Discretize a partial differential equation (PDE), and recognize the type of PDE.

CO2: Formulate finite-difference and finite-volume schemes of the necessary order (spatial and temporal discretization).

CO3: Choose the finite-difference/finite-volume method and the number of boundary conditions based on the type of PDE.

CO4: Understand the various discretization errors and their implications for the outcome.

CO5: Learn about iterative procedures and error damping using iterative strategies.

CO6: Develop conventional second-order finite-volume algorithms using limiters.

CO7: Use advanced CFD tools to evaluate complex fluid-flow systems.

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).