B. Tech. Programme from the Department of Mechanical Engineering

Semester wise detailed syllabus

Sl. No.	Subject Code	SEMESTER I	L	T	P	C
1.	MA1101	Calculus and Linear Algebra	3	1	0	4.0
2.	CS1101	Foundations of Programming	3	0	3	4.5
3.	PH1101/ PH1201	Physics	3	1	3	5.5
4.	CE1101/ CE1201	Engineering Graphics	1	0	3	2.5
5.	EE1101/ EE1201	Electrical Sciences	3	0	3	4.5
6.	HS1101	English for Professionals	2	0	1	2.5
TOTAL			**15**	**2**	**13**	**23.5**

Course Number	MA1101
Course Credit (L-T-P-C)	3-1-0-4
Course Title	Calculus and Linear Algebra
Learning Mode	Lectures and Tutorials
Learning Objectives	To provide the essential knowledge of basic tools of Differential Calculus, Integral Calculus, Vector spaces and Matrix Algebra.
Course Description	This course provides a foundation for Calculus and Linear Algebra. Topics related to properties of single and two variable functions along with their applications will be discussed. In addition fundamentals of linear algebra and matrix theory with applications will also be discussed.
Course Content	**Differential Calculus (12 Lectures)**: Limit and continuity of one variable function (including ε-δ definition). Limit, continuity and differentiability of functions of two variables, Tangent plane and normal, Change of variables, chain rule, Jacobians, Taylor's Theorem for two variables, Extrema of functions of two or more variables, Lagrange's method of undetermined multipliers. **Integral Calculus (10 Lectures)**: Riemann integral for one variable functions, Double and Triple integrals, Change of order of integration. Change of variables, Applications of Multiple integrals such as surface area and volume. **Vector Spaces (12 Lectures)**: Vector spaces (over the field of real numbers), subspaces, spanning set, linear independence, basis and dimension. Linear transformations, range and null space, rank-nullity theorem, matrix of a linear transformation. **Matrix Algebra (8 Lectures)**: Elementary operations and their use in getting the rank, inverse of a matrix and solution of linear simultaneous equations, Orthogonal, symmetric, skew-symmetric, Hermitian, skew-Hermitian, normal and unitary matrices and their elementary properties, Eigenvalues and Eigenvectors of a matrix, Cayley-Hamilton theorem, Diagonalization of a matrix.
Learning Outcome	Students completing this course will be able to: 1. Understand various properties of functions such as limit, continuity and differentiability. 2. Learn about integrations in various dimension and their applications. 3. learn about the concept of basis and dimension of a vector space. 4. define Linear Transformations and compute the domain, range, kernel, rank, and nullity of a linear transformation. 5. compute the inverse of an invertible matrix. 6. solve the system of linear equations. 7. Apply linear algebra concepts to model, solve, and analyze real-world problems.
Assessment Method	Quiz /Assignment/ MSE / ESE

Textbooks:

1. Thomas, G. B., Hass, J., Heil, C. and Weir M. D., "Thomas' Calculus", 14th Ed., Pearson Education, 2018
2. Kreyszig, E., "Advanced Engineering Mathematics", 10th Ed., Wiley India Pvt. Ltd, 2015

Reference Books:

1. Jain, R. K. and Iyenger, S. R. K., "Advanced Engineering Mathematics", 5th Ed., Narosa Publishing House, 2017
2. Axler, S., "Linear Algebra Done Right", 3rd Ed., Springer Nature, 2015
3. Strang, G., "Linear Algebra and Its Applications" 4th Ed., Cengage India Private Limited, 2005

Course Number	CS1101
Course Credit	3-0-3-4.5
Course Title	**Foundations of Programming**
Learning Mode	Offline
Learning Objectives	• To understand the fundamental concepts of programming • To develop the basic problem-solving skills by designing algorithms and implementing them. • To learn about various data types, control statements, functions, arrays, pointers, and file handling. • To achieve proficiency in debugging and testing a C program
Course Description	This introductory course provides a solid foundation in programming principles and techniques. Designed for students with little to no prior programming experience, it covers fundamental concepts such as variables, data types, control structures, functions, and basic data structures. Students will learn to write, debug, and execute programs using a high-level programming language. Emphasis is placed on developing problem-solving skills, logical thinking, and the ability to write clear and efficient code. By the end of the course, students will be equipped with the essential skills needed to pursue more advanced studies in computer science and software development.
Course Outline	Introduction and Programming basics, Expressions Control and Iterative statements, Functions, Arrays, Recursion vs. Iteration Pointers, 2D-Array with pointers, Structures, String, Dynamic memory allocation, File handling, Contemporary programming languages, and applications **Practical component**: Lab to be conducted on a 3-hour slot weekly. It will be conducted with the theory course so the topics for problems given in the lab are already initiated in the theory class.
Learning Outcome	• Understanding of Basic Syntax and Structure in C language • Proficiency in Data Types, Operators, and Control Structures • Function Implementation and learn to use them appropriately • Efficient Use of Arrays and Strings • Pointer Utilization • Ability to perform dynamic memory allocation and deallocation using malloc (), calloc (), realloc (), and free () functions. • Structured data management with structures and unions • Exposure of file Handling • Learning debugging and error Handling
Assessment Method	Internal (Quiz/Assignment/Project), Mid-Term, End-Term

Suggested Reading

- Knuth, Donald E. The art of computer programming, volume 4A: combinatorial algorithms, part 1. Pearson Education India, 2011.
- P.J. Deitel and H.M. Deitel, C How To Program, Pearson Education (7th Edition)
- Brian W. Kernighan and Dennis M. Ritchie, The C Programming Language, Prentice−Hall
- A. Kelley and I. Pohl, A Book on C, Pearson Education (4th Edition)
- K. N. King, C PROGRAMMING A Modern Approach, W. W. Norton & Company

Course Number	**PH1101/PH1201**
Course Credit	3-1-3-5.5
Course Title	Physics
Learning Mode	Lectures and Tutorials
Learning Objectives	Complies with Program Goals 1 and 2
Course Description	This course deals with fundamentals in Classical mechanics, Waves and Oscillations and Quantum Mechanics. As a prerequisite, the mathematical preliminaries such as coordinate systems, vector calculus etc will be discussed in the beginning.
Course Outline	Orthogonal coordinate systems (Plane polar, Spherical, Cylindrical), concept of generalised coordinates, generalised velocity and phase space for a mechanical system, Introduction to vector operators, Gradient, divergence, curl and Laplacian in different co-ordinate systems. Central force problem and its applications. Rigid body rotation, vector nature of angular velocity, Finding the principal axes, Euler's equations; Gyroscopic motion and its application; Accelerated frame of reference, Fictitious forces. Potential energy and concept of equilibrium, Lennard-Jones and double-well potentials, Small oscillations, Harmonic oscillator, damped and forced oscillations, resonance and its different examples, oscillator states in phase space, coupled oscillations, normal modes, longitudinal and transverse waves, wave equation, plane waves, examples two- and three-dimensional waves. Michelson-Morley experiment, Lorentz transformation, Postulates of special theory of relativity, Time dilation and length contraction, Applications of special theory of relativity.
Learning Outcome	Complies with PLO 1a, 2a, 3a
Assessment Method	Quiz, Assignments and Exams

Suggested Readings:

Textbooks:

1. Engineering Mechanics, M. K. Harbola, 2nd ed., Cengage, 2012
2. D. Kleppner and R. J. Kolenkow, An introduction to Mechanics, Tata McGraw-Hill, New Delhi, 2000.
3. I. G. Main, Oscillations and Waves
4. H. G. Pain, The Physics of Vibrations and Waves, 1968
5. Frank S. Crawford, Berkeley Physics Course Vol 3: Waves and Oscillations, McGraw Hill, 1966.

References:

1. R. P. Feynman, R. B. Leighton and M. Sands, The Feynman Lecture in Physics, Vol I, Narosa Publishing House, New Delhi, 2009.
2. David Morin, Introduction to Classical Mechanics, Cambridge University Press, NY, 2007.
3. P. C. Deshmukh, Foundations of Classical Mechanics, Cambridge University Press, 2019

Course code	**CE1101/CE1201**
Course Credit (L-T-P-C)	1-0-3-2.5
Course Title	**Engineering Graphics**
Learning Mode	Lectures and Practical
Learning Objectives	Complies with PLO-1a 1. The course on engineering drawing is designed to introduce the fundamentals of technical drawing as an important form of conveying information. 2. Apply principles of engineering visualization and projection theory to prepare engineering drawings, using conventional and modern drawing tools. 3. Practice drawing orthographic projections, isometric views, and sectional views, of simple and combined solids in different orientations.
Course Description	This course will introduce drawing as a tool to represent a complex three-dimensional object on two-dimensional paper through methods of projections. The course explains the use of different drafting tools and the importance of conventions for uniformity and standardization of the interpretation of the drawings.
Course Outline	Fundamental of engineering drawing, line types, dimensioning, and scales. Conic sections: ellipse, parabola, hyperbola; cycloidal curves. Principle of projection, method of projection, orthographic projection, plane of projection, first angle of projection, Projection of points, lines, planes and solids. Section of solids: Sectional views of simple solids- prism, pyramid, cylinder, cone, sphere; the true shape of the section. Methods of development, development of surfaces. Isometric projections: construction of isometric view of solids and combination of solids from orthographic projections. Introduction to AutoCad and solving isometric problems.
Learning Outcome	After attending this course, the following outcomes are expected: a) The student will understand the basic concepts of engineering drawing. b) The student will be able to use basic drafting tools, drawing instruments, and sheets. c) The student will be able to represent three-dimensional simple and combined solid objects on two-dimensional paper. d) The student will be able to visualize and interpret the orientation of simple and combine solid objects.
Assessment Method	Laboratory Assignments (30%), Mid-semester examination (25%) and End-semester examination (45%).

Suggested Readings:

Textbooks:

1. N.D. Bhatt, Engineering Drawing, Charotar Publishing House.
2. Agrawal & Agrawal, Engineering Drawing, McGraw Hill.
3. Jolhe, Engineering Drawing.

References:

1. Engineering Drawing and Design by David Madsen

Course Number	EE1101/EE1201
Course Credit	3-0-3-4.5
Course Title	Electrical Sciences
Learning Mode	Lectures and Experiments
Learning Objectives	Complies with Program goals 1, 2 and 3
Course Description	The course is designed to meet the requirements of all B. Tech programmes. The course aims at giving an overview of the entire electrical engineering domain from the concepts of circuits, devices, digital systems and magnetic circuits.
Course Outline	Circuit Analysis Techniques, Circuit elements, Simple RL and RC Circuits, Kirchoff's law, Nodal Analysis, Mesh Analysis, Linearity and Superposition, Source Transformations, Thevenin's and Norton's Theorems, Time Domain Response of RC, RL and RLC circuits, Sinusoidal Forcing Function, Phasor Relationship for R, L and C, Impedance and Admittance, Instantaneous power, Real, reactive power and power factor. Semiconductor Diode, Zener Diode, Rectifier Circuits, Clipper, Clamper, UJT, Bipolar Junction Transistors, MOSFET, Transistor Biasing, Transistor Small Signal Analysis, Transistor Amplifier and their types, Operational Amplifiers, Op-amp Equivalent Circuit, Practical Op-amp Circuits, Power Opamp, DC Offset, Constant Gain Multiplier, Voltage Summing, Voltage Buffer, Controlled Sources, Instrumentation Amplifier, Active Filters and Oscillators. Number Systems, Logic Gates, Boolean Theorem, Algebraic Simplification, K-map, Combinatorial Circuits, Encoder, Decoder, Combinatorial Circuit Design, Introduction to Sequential Circuits. Magnetic Circuits, Mutually Coupled Circuits, Transformers, Equivalent Circuit and Performance, Analysis of Three-Phase Circuits, Power measurement in three phase system, Electromechanical Energy Conversion, Introduction to Rotating Machines (DC and AC Machines). <u>Laboratory:</u> Experiments to verify Circuit Theorems; Experiments using diodes and bipolar junction transistor (BJT): design and analysis of half -wave and full-wave rectifiers, clipping and clamping circuits and Zener diode characteristics and its regulators, BJT characteristics (CE, CB and CC) and BJT amplifiers; Experiment on MOSFET characteristics (CS, CG, and CD), parameter extraction and amplifier; Experiments using operational amplifiers (op-amps): summing amplifier, comparator, precision rectifier, Astable and Monostable Multivibrators and oscillators; Experiments using logic gates: combinational circuits such as staircase switch, majority detector, equality detector, multiplexer and demultiplexer; Experiments using flip-flops: sequential circuits such as non-overlapping pulse generator, ripple counter, synchronous counter, pulse counter and numerical display; Power Measurement by two Wattmeter method; Open and Short Circuit Tests of Transformer.
Learning Outcomes	Complies with PLO 1a, 2a and 3a
Assessment Method	Quiz, Assignments and Exams

Texts/References

1. C. K. Alexander, M. N. O. Sadiku, Fundamentals of Electric Circuits, 3rd Edition, McGraw-Hill, 2008.
2. W. H. Hayt and J. E. Kemmerly, Engineering Circuit Analysis, McGraw-Hill, 1993.
3. R. L. Boylestad and L. Nashelsky, Electronic Devices and Circuit Theory, 6th Edition, PHI, 2001.
4. M. M. Mano, M. D. Ciletti, Digital Design, 4th Edition, Pearson Education, 2008.
5. Floyd, Jain, Digital Fundamentals, 8th Edition, Pearson.
6. David V. Kerns, Jr. J. David Irwin, Essentials of Electrical and Computer Engineering, Pearson, 2004.
7. Donald A Neamen, Electronic Circuits; analysis and Design, 3rd Edition, Tata McGraw-Hill Publishing Company Limited.
8. Adel S. Sedra, Kenneth C. Smith, Microelectronic Circuits, 5th Edition, Oxford University Press, 2004.
9. A. E. Fitzgerald, C. Kingsley Jr., S. D. Umans, Electric Machinery, 6th Edition, Tata McGraw-Hill, 2003.
10. D. P. Kothari, I. J. Nagrath, Electric Machines, 3rd Edition, McGraw-Hill, 2004.
11. Del Toro, Vincent. "Principles of electrical engineering." (No Title) (1972).

Course Number	HS1101
Course Credit	L-T-P-W: 2-0-1-2.5
Course Title	English for Professionals
Learning Mode	Offline
Learning Objectives	This course aims to help the students **(a)** attain proficiency in written English through the construction of grammatically correct sentences, utilization of subject-verb agreement principles, mastery of various tenses, and effective deployment of active and passive voice to ensure coherent and impactful written expression; **(b)** enhance oral communication skills by honing public speaking abilities, acquiring strategies to deliver persuasive presentations, and cultivating a polished telephone etiquette, enabling confident and articulate verbal communication; **(c)** foster active listening capabilities by recognizing different types of listening, and applying proven methods and strategies to improve active listening skills; **(d)** strengthen reading skills, including comprehension, interpretation, and critical analysis, to grasp diverse written materials and derive meaning from various types of texts encountered in academic and professional contexts; **(e)** develop adeptness in written communication for business purposes, encompassing the understanding of essential writing elements, mastery of appropriate writing styles thereby enhancing prospects for successful job interviews and subsequent professional endeavors.
Course Description	This academic course on communication skills aims to equip students with fluency in spoken and written English for effective expression in both academic and professional settings. By focusing on essential communication principles and providing practical experiences, students develop clarity, precision, and confidence in their communication. Through interactive discussions and exercises, students enhance critical thinking and adaptability in diverse contexts. Upon completion, students will excel in formal presentations, group discussions, and persuasive writing, enhancing their overall communication proficiency.
Course Outline	**Unit I:** Introduction to professional communication – LSRW - Phonetics and phonology Sounds in English Language – production and articulation – rhythm and intonation – connected speech - Basic Grammar and Advanced Vocabulary Sounds in English Language – production and articulation – rhythm and intonation – connected speech – persuading and negotiating – brevity and clarity in language. Unit II: Characteristics of Technical Communication: Types of communication and forms of communication - Formal and informal communication Verbal and non-Verbal Communication – Communication barriers and remedies Intercultural communication – neutral language Unit III: Comprehension and Composition – summarization, precis writing Business Letter Writing CV/ Resume – E-Communication Unit IV: Statement of Purpose, Writing Project Reports, Writing research proposal, writing abstracts, developing presentations, interviews – combating nervousness Tutorial: Listening Exercises, Speaking Practice (GDs, and Presentations), and Writing Practice Learning Outcome • Attain proficiency in written English, enabling the construction of grammatically correct sentences and coherent written expression through the use of appropriate grammar, tenses, and voice. • Enhance oral communication skills, including public speaking, persuasive presentation, and polished telephone etiquette, fostering confident and articulate verbal expression. • Cultivate active listening abilities, recognizing different listening types, overcoming obstacles, and employing strategies for attentive and effective communication. • Develop proficient written communication skills for business purposes, demonstrating understanding of essential writing elements, appropriate styles, and the creation of reports, notices, agendas, and minutes that effectively convey information.
Assessment Method	Class test + Quiz = 20%; Mid-semester = 25%; Assignment = 15%; End semester = 40%

Suggested Reading

1. Balzotti, Jon. Technical Communication: A Design-Centric Approach. Routledge, 2022.
2. Kaul, Asha, Business Communication. PHI Learning Pvt. Ltd. 2009
3. Laplante, Phillip A. Technical Writing: A Practical Guide for Engineers, Scientists, and Nontechnical Professionals. CRC Press, 2018.
4. Lawson, Celeste, et al. Communication Skills for Business Professionals, Second Edition. CUP, 2019.
5. Sharon Gerson and Steven Gerson. Technical Writing: Process and Product (8th Edition), London: Longman, 2013
6. Rentz, Kathryn, Marie E. Flatley & Paula Lentz. Lesikar's Business Communication Connecting in a Digital world, McGraw-Hill, Irwin.2012
7. Allan & Barbara Pease. The Definitive Book of Body Language, New York, Bantam,2004
8. Jones, Daniel. The Pronunciation of English, New Delhi, Universal Book Stall.2010
9. Savage, Alice. Effective Academic Writing. OUP. 2014
10. Swan and Alter. Oxford English grammar course. OUP. 201

Sl. No.	Subject Code	SEMESTER II	L	T	P	C
1.	MA1201	Probability Theory and Ordinary Differential Equations	3	1	0	4
2.	CS1201	Data Structure	3	0	3	4.5
3.	CH1201/CH1101	Chemistry	3	1	3	5.5
4.	ME1201/ME1101	Mechanical Fabrication	0	0	3	1.5
5.	ME1202/ME1102	Engineering Mechanics	3	1	0	4
6.	IK1201	Indian Knowledge System (IKS)	3	0	0	3
TOTAL			**15**	**3**	**9**	**22.5**

Course Number	MA1201
Course Credit (L-T-P-C)	3-1-0-4
Course Title	Probability Theory and Ordinary Differential Equations
Learning Mode	Lectures and Tutorials
Learning Objectives	To introduce the basic concepts of probability, statistics, and Differential equations.
Course Description	This course aims to cover basic concepts of probability, statistics and ordinary differential equations. In particular, popular distributions, random sampling, various estimators and hypothesis testing will be discussed. Students will also get exposure to the linear ordinary differential equations and their solution techniques.
Course Content	**Probability (12 Lectures)**: Random variables and their probability distributions, Cumulative distribution functions, Expectation and Variance, probability inequalities, Binomial, Poisson, Geometric, negative binomial distributions, Uniform, Exponential, beta, Gamma, Normal and lognormal distributions. **Statistics (10 Lectures)**: Random sampling, sampling distributions, Parameter estimation, Point estimation, unbiased estimators, maximum likelihood estimation, Confidence intervals for normal mean, Simple and composite hypothesis, Type I and Type II errors, Hypothesis testing for normal mean. **Ordinary Differential Equations (20 Lectures)**: First order ordinary differential equations, exactness and integrating factors, Picard's iteration, Ordinary linear differential equations of n-th order, solutions of homogeneous and non-homogeneous equations (Method of variation of parameters). Systems of ordinary differential equations, Power series methods for solutions of ordinary differential equations. Legendre equation and Legendre polynomials, Bessel equation and Bessel functions.
Learning Outcome	Students will get exposure and understanding of: 1. Random variables and their probability distributions 2. Understand popular distributions and their properties 3. Sampling, estimation and hypothesis testing 4. Solution of ordinary differential equations 5. Solution of system of ordinary differential equations 6. Special functions arising as power series solutions of ordinary differential equations
Assessment Method	Quiz /Assignment/ MSE / ESE

Text Books:

1. Hogg, R. V., Mckean, J. and Craig, A. T., “Introduction to Mathematical Statistics”, 8th Ed., Pearson Education India, 2021
2. S.M. Ross “An introduction to Probability Models, Academic Press INC, 11th edition.
3. Miller, I. and Miller, M., “John E. Freund's Mathematical Statistics with Applications”, 8th Ed., Pearson Education India, 2013
4. S. L. Ross, Differential equations, 3rd Edition, Wiley, 1984
5. W. E. Boyce and R. C. Di Prima, Elementary Differential equations and Boundary Value Problems, 7th Edition, Wiley, 2001.

Course Number	CS1201
Course Credit	3-0-3-4.5
Course Title	**Data Structure**
Learning Mode	Offline
Learning Objectives	• Understand the principles and concepts of data structures and their importance in computer science. • Learn to implement various data structures and understand how different algorithms works. • Develop problem-solving skills by applying appropriate data structures to different computational problems. • Achieving proficiency in designing efficient algorithms.
Course Description	This course provides a comprehensive study of data structures and their applications in computer science. It focuses on the implementation, analysis, and use of various data structures such as arrays, linked lists, stacks, queues, trees, and graphs. Through theoretical concepts and practical programming exercises, this course aims to develop problem-solving and algorithmic thinking skills essential for advanced topics in computer science and software development.
Course Outline	• Introduction to Data Structure, • Time and space requirements, Asymptotic notations • Abstraction and Abstract data types • Linear Data Structure: stack, queue, list, and linked structure • Unfolding the recursion • Tree, Binary Tree, traversal • Search and Sorting, • Graph, traversal, MST, Shortest distance • Balanced Tree **Practical component**: Lab to be conducted on a 3-hour slot weekly. It will be conducted with the theory course so the topics for problems given in the lab are already initiated in the theory class.
Learning Outcome	• Understand Data Structure Fundamentals • Implement Basic Data Structures using a programming language • Analyse and Apply Algorithms • Design and Analyse Tree Structures • Understand the usage of graph and its related algorithms • Design and Implement Sorting and Searching Algorithms • Debug and Optimize Code
Assessment Method	Internal (Quiz/Assignment/Project), Mid-Term, End-Term

Suggested Reading

- Alfred V. Aho, John E. Hopcroft, Jeffrey D. Ullman, Data Structures and Algorithms, Published by Addison-Wesley
- Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest and Clifford Stein., Introduction to Algorithms,
- Mark Allen Weiss, Data Structures and Algorithm Analysis in Java
- Robert Sedgewick and Kevin Wayne, Algorithms
- Narasimha Karumanchi, Data Structures and Algorithms Made Easy

Course Number	**CH1201/CH1101**
Course Credit	**3-1-3-5.5**
Course Title	**Chemistry**
Learning Mode	Offline
Learning Objectives	The course aims to lay a foundation for all three branches of chemistry, viz. Organic, Inorganic, and Physical Chemistry. The course aims to nurture knowledge to appreciate the interface of chemistry with other

	science and Engineering branches by combining theoretical concepts and experimental studies.
Course Description	This course introduces basic organic chemistry, inorganic chemistry and Physical chemistry to understand fundamental laws that governs various reactions, reaction rates, equilibrium, and their applications in daily life through relevant experimentation.
Course Outline	**Module 1:** Thermodynamics: The fundamental definition and concept, the zeroth and first law. Work, heat, energy and enthalpies. Second law: entropy, free energy and chemical potential. Change of Phase. Third law. Chemical equilibrium. Conductance of solutions, Kohlrausch's law-ionic mobilities, Basic Electrochemistry. **Module 2:** Coordination chemistry: Crystal field theory and consequences color, magnetism, J.T distortion. Bioinorganic chemistry: Trace elements in biology, heme and non-heme oxygen carriers, haemoglobin and myoglobin; Organometallic chemistry. **Module 3:** Stereo and regio-chemistry of organic compounds, conformational analysis and conformers, Molecules devoid of point chirality (allenes and biphenyls); Significance of chirality in living systems, organic photochemistry, Modern techniques in structural elucidation of compounds (UV–Vis, IR, NMR). **Module 4 (Lab Component):** Experiments based on redox and complexometric titrations; synthesis and characterization of inorganic complexes and nanomaterials; synthesis and characterization of organic compounds; experiments based on chromatography; experiments based on pH and conductivity measurement; experiment related to chemical kinetics and spectroscopy.
Learning Outcome	Students will be able to 1**.** identify organic and inorganic molecules and relate them to daily life applications through experiments. 2. understand important hypothesis, laws and their derivations to intercept physical phenomenon of chemical reactions and apply them in hands-on experiments. 3. understand the importance of organic and inorganic molecules in our body and environment. 4. know important analytical techniques to intercept chemical entity. 5. approach organic and inorganic synthesis as a skillset for drug manufacturing, calculate limiting reagents and yields, use various analytical tools to characterize organic compounds, interpret and ascertain data related to Physical chemistry aspects and know laboratory safety measures, risk factors and scientific report writing skills.
Assessment Method	**Theory**: 20% Quiz and assignment, 30% Mid sem and 50% End semester exams for theory part (4 credits). **Lab**: 60% lab report, lab performance and assignment, 20% End semester exam for practical part, 20% viva/quiz (1.5 credits). **Overall Weightage**: Theory (70%), Lab (30%).

Suggested Reading:

Text books:

1. Vogel's Qualitative Inorganic Analysis, G. Svehla, 7th Edition, Revised, Prentice Hall, 1996.

2. A. J. Elias, S. S. Manoharan and H. Raj, "Experiments in General Chemistry", Universities Press (India) Pvt. Ltd., 1997.
3. A. J. Elias, A Collection of Interesting General Chemistry Experiments, revised edition, Universities Press (India) Pvt. Ltd., 2007.
4. F. Albert Cotton, G. Wilkinson, C. A. Murillo, M. Bochmann, Advanced Inorganic Chemistry - 6th Edition New Delhi: Wiley India, 2008.
5. K. Mukkanti, Practical Engineering Chemistry, B.S. Publications, Hyderabad, 2009.
6. Shriver and Atkins inorganic chemistry / Peter Atkins, Tina Overton, Jonathan Rourke, Mark Weller, Fraser Armstrong-5th Edition – Oxford: UOP. 2012.
7. Atkins' Physical Chemistry, Peter Atkins, Julio de Paula, James Keeler, Oxford University Press, 11th Edition 2017.
8. K. L. Kapoor, A Textbook of Physical Chemistry, Vol: 1, 2 (6th Edition, 2019), Vol: 3 (5th Edition, 2020) MaGraw Hill.
9. G. R. Chatwal, S. K. Anand, Instrumental Methods of Chemical Analysis, 5th Edition, Himalaya Publications, 2023.

	PLO-1	PLO-2	PLO-3	PLO-4	PLO-5	PLO-6	PLO-7	PLO-8
CLO-1	X	X	X	X	X	X	X	X
CLO-2	X	X		X	X			
CLO-3	X	X	X	X		X	X	
CLO-4	X	X		X	X	X	X	X
CLO-5			X	X	X			X

Course Number	**ME1201/ME1101**
Course Credit	**0-0-3-1.5**
Course Title	**Mechanical Fabrication**
Learning Mode	Fabrication work – hands on fabrication work in Workshop
Learning Objectives	Complies with PLOs 3-4. • This course aims to develop the concepts and skills of various mechanical fabrication methods. • Fabrication of metallic and non-metallic components, fabrication using bulk and sheet metals, subtractive and additive manufacturing methods, and assemble the parts
Course Description	This course is designed to fulfil the need of hand on experience about various approaches (conventional and CNC, subtractive and additive) of mechanical fabrication approaches. Prerequisite: NIL
Course Outline	The jobs for various shops should be planned such that they are the parts of an assembled item. The student groups will fabricate different parts in various shops which will involve some amount of their creativeness/input particularly in design and/or planning. Various components as required for the assembled part can be made using the following shops: **Sheet Metal Working:** Development, sheet cutting and fabrication of designated job using sheet metal (ferrous/nonferrous); Joining of required portions by soldering, in case part is desired to be made leak proof. **Pattern Making and Foundry:** Making of suitable pattern (wood); making of sand mould, melting of non-ferrous metal/alloy (Al or Al alloys), pouring, solidification. Observation/identification of various defects appeared on the component. **Joining:** Butt/lap/corner joint job fabrication as required of low carbon steel plates; weld quality inspection by dye-penetration test (non-destructive testing approach)of the component made. Demonstration of semi-automatic Gas Metal Arc welding (GMAW). **Conventional machining:** Operations on lathe and vertical milling to fabricate the required component. The fabrication of the component should cover various lathe operations like straight turning, facing, thread cutting, parting off etc., and operations using indexing mechanism on vertical milling. **CNC centre:** Fundamentals of CNC programming using G and M code; setting and operations of job using CNC lathe or milling, tool reference, work reference, tool offset, tool radius compensation to fabricate the component with a designed profile on Al/Al-alloy plate. **3D printing (Fused Filament Fabrication): (2 weeks)** Create the model, select appropriate slicing and path for fabrication of a 3D job by layer deposition (additive manufacturing approach) using polymeric material. Demonstration on pattern fabrication using 3D printing.
Learning Outcome	• This course would enable the students to develop the concept of design, fabrication (subtractive and additive) for various engineering applications**.** Fabrication of components and assemble them. • The practical skill and hands on experience for various fabrication methods from bulk, sheet metal using conventional as well as CNC machines.
Assessment Method	Fabrication of components in each of the shops required for assembly of the given part; submission of reports for each shop, and quiz assessment.

Text and Reference books:

1. Hajra Choudhury, HazraChoudhary and Nirjhar Roy, 2007, Elements of Workshop Technology, vol. I,Mediapromoters and Publishers Pvt. Ltd.
2. W A J Chapman, Workshop Technology, 1998, Part -1, 1st South Asian Edition, Viva Book Pvt Ltd.

3. P.N. Rao, 2009, Manufacturing Technology, Vol.1, 3rd Ed., Tata McGraw Hill Publishing Company.
4. M.Adithan, B.S. Pabla, 2012, CNC machines, New Age International Publishers

Course Number	**ME1202/ ME1102**
Course Number	**Engineering Mechanics**
L-T-P-C	3-1-0-4
Pre-requisites	Nil
Semester	Spring
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 1, 4 • The objective of this first course in mechanics is to enable engineering students to analyze basic mechanics problems and apply vector-based approach to solve them.
Course Outline	1. **Rigid body statics**: Equivalent force system. Equations of equilibrium, Free body diagram, Reaction, Static indeterminacy. 2. **Structures**: 2D truss, Method of joints, Method of section. Beam, Frame, types of loading and supports, axial force, Bending moment, Shear force and Torque Diagrams for a member. 3. **Friction**: Dry friction (static and kinetic), wedge friction, disk friction (thrust bearing), belt friction, square threaded screw, journal bearings, Wheel friction, Rolling resistance. **4. Centroid and Moment of Inertia** 5. **Introduction to stress and strain**: Definition of Stress, Normal and shear Stress. Relation between stress and strain, Cauchy formula. **Stress in an axially loaded member and stress due to torsion in axisymmetric section**
Learning Outcomes:	Following learning outcomes are expected after going through this course. • Learn and apply general mathematical and computer skills to solve basic mechanics problems. • Apply the vector-based approach to solve mechanics problems.
Assessment Method	Mid semester examination, End semester examination, Class test/Quiz, Tutorials

Reference Books

1. H. Shames, Engineering Mechanics: Statics and dynamics, 4th Ed, PHI, 2002.
2. F. P. Beer and E. R. Johnston, Vector Mechanics for Engineers, Vol I - Statics, 3rd Ed, Tata McGraw Hill, 2000.
3. J. L. Meriam and L. G. Kraige, Engineering Mechanics, Vol I - Statics, 5th Ed, John Wiley, 2002.
4. E.P. Popov, Engineering Mechanics of Solids, 2nd Ed, PHI, 1998.
5. F. P. Beer and E. R. Johnston, J.T. Dewolf, and D.F. Mazurek, Mechanics of Materials, 6th Ed, McGraw Hill Education (India) Pvt. Ltd., 2012.

Course Number	**ME1101/ME1201**
Course Credit	L-T-P-C : **0-0-3-1.5**
Course Title	**Mechanical Fabrication**
Learning Mode	Fabrication work – hands on fabrication work in Workshop
Learning Objectives	Complies with PLOs 3-4. • This course aims to develop the concepts and skills of various mechanical fabrication methods. • Fabrication of metallic and non-metallic components, fabrication using bulk and sheet metals, subtractive and additive manufacturing methods, and assemble the parts
Course Description	This course is designed to fulfil the need of hand on experience about various approaches (conventional and CNC, subtractive and additive) of mechanical fabrication approaches. Prerequisite: NIL
Course Outline	The jobs for various shops should be planned such that they are the parts of an assembled item. The student groups will fabricate different parts in various shops which will involve some amount of their creativeness/input particularly in design and/or planning. Various components as required for the assembled part can be made using the following shops: **Sheet Metal Working:** Development, sheet cutting and fabrication of designated job using sheet metal (ferrous/nonferrous); Joining of required portions by soldering, in case part is desired to be made leak proof. **Pattern Making and Foundry:** Making of suitable pattern (wood); making of sand mould, melting of non-ferrous metal/alloy (Al or Al alloys), pouring, solidification. Observation/identification of various defects appeared on the component. **Joining:** Butt/lap/corner joint job fabrication as required of low carbon steel plates; weld quality inspection by dye-penetration test (non-destructive testing approach)of the component made. Demonstration of semi-automatic Gas Metal Arc welding (GMAW). **Conventional machining:** Operations on lathe and vertical milling to fabricate the required component. The fabrication of the component should cover various lathe operations like straight turning, facing, thread cutting, parting off etc., and operations using indexing mechanism on vertical milling. **CNC centre:** Fundamentals of CNC programming using G and M code; setting and operations of job using CNC lathe or milling, tool reference, work reference, tool offset, tool radius compensation to fabricate the component with a designed profile on Al/Al-alloy plate. **3D printing (Fused Filament Fabrication): (2 weeks)** Create the model, select appropriate slicing and path for fabrication of a 3D job by layer deposition (additive manufacturing approach) using polymeric material. Demonstration on pattern fabrication using 3D printing.
Learning Outcome	• This course would enable the students to develop the concept of design, fabrication (subtractive and additive) for various engineering applications**.** Fabrication of components and assemble them. • The practical skill and hands on experience for various fabrication methods from bulk, sheet metal using conventional as well as CNC machines.
Assessment Method	Fabrication of components in each of the shops required for assembly of the given part; submission of reports for each shop, and quiz assessment.

Text and Reference books:

5. Hajra Choudhury, HazraChoudhary and Nirjhar Roy, 2007, Elements of Workshop Technology, vol. I,Mediapromoters and Publishers Pvt. Ltd.

6. W A J Chapman, Workshop Technology, 1998, Part -1, 1st South Asian Edition, Viva Book Pvt Ltd.
7. P.N. Rao, 2009, Manufacturing Technology, Vol.1, 3rd Ed., Tata McGraw Hill Publishing Company.
8. M.Adithan, B.S. Pabla, 2012, CNC machines, New Age International Publishers

Course Number	**ME1102/ME1202**
Course Number	**Engineering Mechanics**
L-T-P-C	3-1-0-4
Pre-requisites	Nil
Semester	Spring
Learning Mode	Lectures

Learning Objectives

Complies with PLOs 1, 4

- The objective of this first course in mechanics is to enable engineering students to analyze basic mechanics problems and apply vector-based approach to solve them.

Course Outline

6. **Rigid body statics**: Equivalent force system. Equations of equilibrium, Free body diagram, Reaction, Static indeterminacy.
7. **Structures**: 2D truss, Method of joints, Method of section. Beam, Frame, types of loading and supports, axial force, Bending moment, Shear force and Torque Diagrams for a member.
8. **Friction**: Dry friction (static and kinetic), wedge friction, disk friction (thrust bearing), belt friction, square threaded screw, journal bearings, Wheel friction, Rolling resistance.
9. **Centroid and Moment of Inertia**
10. **Introduction to stress and strain**: Definition of Stress, Normal and shear Stress. Relation between stress and strain, Cauchy formula.
11. **Stress in an axially loaded member and stress due to torsion in axisymmetric section**

Learning Outcomes:

Following learning outcomes are expected after going through this course.

- Learn and apply general mathematical and computer skills to solve basic mechanics problems.
- Apply the vector-based approach to solve mechanics problems.

Assessment Method

Mid semester examination, End semester examination, Class test/Quiz, Tutorials

Reference Books

1. H. Shames, Engineering Mechanics: Statics and dynamics, 4th Ed, PHI, 2002.
2. F. P. Beer and E. R. Johnston, Vector Mechanics for Engineers, Vol I - Statics, 3rd Ed, Tata McGraw Hill, 2000.
3. J. L. Meriam and L. G. Kraige, Engineering Mechanics, Vol I - Statics, 5th Ed, John Wiley, 2002.
4. E.P. Popov, Engineering Mechanics of Solids, 2nd Ed, PHI, 1998.
5. F. P. Beer and E. R. Johnston, J.T. Dewolf, and D.F. Mazurek, Mechanics of Materials, 6th Ed, McGraw Hill Education (India) Pvt. Ltd., 2012.

Sl. No.	Subject Code	SEMESTER III	L	T	P	C
1.	ME2101	Dynamics	3	1	0	4
2.	ME2102	Thermodynamics	3	1	0	4
3.	ME2103	Fluid Mechanics	3	1	2	5
4.	ME2104	Engineering Materials	3	0	2	4
5.	HS21XX	HSS Elective - I	3	0	0	3
TOTAL			**15**	**3**	**4**	**20**

Course Name	**Dynamics**
Course Number	**ME2101**
L-T-P-C	3- 1- 0- 4
Pre-requisites	Nil
Semester	Third
Learning Mode	Lectures
Course Learning Objectives	
	Complies with PLOs 1 and 4. The objective of this course is to introduce students to the fundamental principles and methods of dynamics. Students will be introduced to specific problems on modelling of engineering systems using principles of dynamics. Some of the exercise problems will be solved using computer based programs.
Course Content	
	1. Kinematics of Particles: Rectilinear motion, curvilinear motion rectangular, normal, tangential, polar, cylindrical, spherical (coordinates), relative and constrained motion, space curvilinear motion. 2. Kinetics of Particles: Force, mass and acceleration, work and energy, impulse and momentum, impact. Introduction to central force motion. 3. Kinetics of a system of particles, 4. Center of Gravity and Moment of Inertia: First and second moment of mass, radius of gyration, parallel axis theorem, product of inertia, rotation of axes and principal moment of inertia, thin plates, composite bodies. 5. Potential energy, impulse-momentum and associated conservation principles, Euler equations of motion and its application. 6. Introduction to Variational principles, Lagrange's equation, Hamilton's principle. 7. Equation of motion in Eulerian angles. 8. Vibration of a single spring-mass-dashpot system: Free and forced vibration, damping resonance, magnification factor, amplitude and phase plot for a harmonically excited single degree of freedom system. Linear Stability (Infinitesimal Stability)
Learning Outcomes	Following learning outcomes are expected after going through this course. a) Learn and apply general mathematical and computer skills to solve dynamics problems. b) Application of Newton's laws of motion, work energy principles, and momentum conservation principles in various coordinate systems for single particles, system of particles, and rigid bodies. c) c) Introductory understanding of vibration of simple mechanical systems.
Assessment Method	Mid Semester Examination, End Semester examination, Class test & quiz, Assignment, Class Performance and Viva

Texts and References	
	1. I. H. Shames, Engineering Mechanics: Statics and dynamics, 4th Ed, PHI, 2002. 2. F. P. Beer and E. R. Johnston, Vector Mechanics for Engineers, Vol II - Dynamics, 3rd Ed, Tata McGraw Hill, 2000. 3. J. L. Meriam and L. G. Kraige, Engineering Mechanics, Vol II - Dynamics, 5th Ed, John Wiley, 2002. 4. L. Meirovitch, Methods of analytical dynamics, Dover Publication, 2007.

Course Name	**Thermodynamics**
Course Number	**ME2102**
L-T-P-C	3- 1- 0- 4
Pre-requisites	Nil
Semester	Third
Learning Mode	Lectures
Course Learning Objectives	
	Complies with PLOs 2 and 4. 1. To develop the basic understanding of classical thermodynamics and principles of engineering applications 2. To develop skills to formulate and analyze thermodynamic problems involving control volumes and control masses
Course Content	
	Thermodynamic systems: Macroscopic and microscopic view, system and control volume, states and properties, processes; Properties of pure substances and steam: Phase changes, steam tables and Mollier diagram, Heat and work; Zeroth law; First law: for systems and control volumes, enthalpy, Applications of first law: closed and open systems, SSSF, USUF, Second law: Carnot cycle, entropy, corollaries of the second law; Applications of second law: closed and open systems, vapor compression and Rankine cycle; irreversibility, availability, exergy; Thermodynamic relations; Properties of mixtures of ideal gases; Third law of thermodynamics; Introduction to psychrometry
Learning Outcomes	The course has been designed to achieve the following outcomes: 1. Understanding of the basic concepts of engineering thermodynamics. 2. Understanding of the thermodynamic properties of pure substances at different states. 3. Acquire basic knowledge about thermodynamic cycles (a) to produce mechanical power from heat, and (b) to keep a place cool and comfortable. 4. Analyse thermodynamic processes for maximum feasible efficiency. 5. Select an engineering approach to problem-solving based on the properties of substances and the laws of thermodynamics.
Assessment Method	Mid Semester Examination, End Semester examination, Class test & quiz, Assignment, Class Performance and Viva
Texts and References	
	Textbook: 1. C Borgnakke& R E Sonntag, Fundamentals of Thermodynamics, 7th Edition, John Wiley, 2009. 2. Y. A. Cengel and M. A. Boles, Thermodynamics: An Engineering Approach, 7th Edition, Tata McGraw Hill, 2017. 3. P. K. Nag, Engineering Thermodynamics, Fifth Edition, McGraw Hill Education, 2013

Course Name	**Fluid Mechanics**
Course Number	**ME2103**
L-T-P-C	3-1-2-5
Pre-requisites	Nil
Semester	Third
Learning Mode	Lectures and Practical
Course Learning objectives	
	Complies with PLOs 2 and 4. 1. To develop the basic understanding of fluid statics and dynamics 2. To develop analytical skills to deal with various types of fluid flow problems 3. Laboratory sessions are designed for developing experimental skills
Course Content	
	Introduction: Definition and classification of fluids, Fluid as a continuum, Properties of fluids, **Dimensional Analysis and Similitude:** Buckingham-pi theorem, Similarities-geometric, kinematic and dynamic. **Fluid Statics:** Pascal's Law, Submerged surfaces Buoyancy and Stability , Stability of submerged bodies, Fluid in a Rigid Body Motion, **Fluid Kinematics:** Lagrangian and Eulerian Approaches, Flow lines, Features of fluid Motion, **Potential flows:** stream and velocity potential function, basic flows, doublet, Blunt body, flow past a stationary and rotating cylinders. **Conservation Equations:** Reynolds Transport Theorem, Integral and differential equations for mass, momentum and energy conservation. **Steady Incompressible Viscous Flows:** Flow between infinite parallel plates, Couette Flow, Hagen-Poiseuille Flow, Losses in a pipe, Pipe networks, **Boundary layer flow:** Prandtl boundary layer equations, Blasius Solution Von Karman Momentum Integral Equation, Boundary layer separation, etc., **Turbulent Flows:** character of turbulence, Reynolds-averaged Navier-Stokes equation, Anatomy of turbulent boundary layer, Prandtl mixing length model. **Introduction to Compressible Flows:** Velocity of sound, Effect of Mach number on flow compressibility
List of experiments	
	1. Stability of floating bodies 2. Centre of pressure 3. PIV measurements (DST-FIST facility: No.SR/FST/ET-II/2018/240(C)) 4. Reynolds Experiment 5. Bernoulli's apparatus 6. Wind tunnel experiments 7. Venturimeter and orificemeter 8. Pitot-tube 9. Losses in pipe 10. Notch/Weir
Learning Outcomes	1. Students should be able to demonstrate the knowledge of fluids, flow behavior, and flow system design 2. Students should be able to apply the fluid flow concepts on practical systems and provide solution to the problems associated with them
Assessment Method	Mid Semester Examination, End Semester examination, Class test & quiz, Assignment, Class Performance and Viva, Practical Exam
Texts and References	

	Textbook: 1. F. M. White, 2016, Fluid Mechanics, 8th Ed, McGraw-Hill. 2. B. R. Munson, D. F. Young and T. H. Okhiishi, 2002, Fundamentals of Fluid Mechanics, 4th Ed, John Wiley, 3. M. K. Khan, 2015, Fluid Mechanics and Machinery, Oxford University Press. **References:** 1. Cengel and Cimbala, 2019, Fluid Mechanics: Fundamentals and Applications, 4th Edition, McGraw-Hill. 2. R. W. Fox, A.T. McDonald and J.W. Mitchell, 2020, Introduction to Fluid Mechanics, 10th Ed, Wiley. 3. V. Streeter, E. B. Wylie, and K.W. Bedford, 2017, Fluid Mechanics, 9th Edition, McGraw-Hill. 4. Irwing Shames, 2002, Mechanics of Fluids, 4th Ed., McGraw-Hill. 5. P. Kundu, I. M. Cohen, and D.R. Dowling, 2015, Fluid Mechanics, 6th Ed., Elsevier. 6. J.A. Fay, 2008, Introduction to Fluid Mechanics, PHI Learning Pvt Ltd., New Delhi 7. Sawan S. Sinha, 2024, Fundamentals of Fluid Mechanics, Ane Books Pvt. Ltd.

Course Name	**Engineering Materials**
Course Number	**ME2104**
L-T-P-C	3-0-2-4
Pre-requisites	Nil
Semester	Third
Learning Mode	Lectures and Practical
Course Learning Objectives	
	Complies with PLOs 1, 3 and 4. 1. Introduce the fundamental science and engineering of materials. 2. Introduce the standard testing procedures to evaluate the mechanical properties of materials. 3. Approaches to alter the mechanical properties of materials and evaluate its performance.
Course Content	
	Crystal imperfections: point defects, line defects, surface defects. Characteristics of dislocations, generation of dislocations. Bonds in solids and characteristics of Metallic bonding, Deformation mechanisms and Strengthening mechanisms in structural materials. **Phase diagrams:** Principles and various types of phase diagrams, Iron carbon phase diagrams. **Principles of solidification:** Structural evaluation during solidification of metals and alloys. **Heat treatment of steels and CCT diagrams**: Pearlitic, martensitic, bainitic transformation in steel during heat treatment. **Hot working and cold working of metals:** recovery, re-crystallization and grain growth, Fracture, Fatigue and creep phenomenon in metallic materials. General classifications, properties and applications of alloy steels, tool steels, stainless steels, cast irons, Nonferrous materials like copper base alloys, aluminum base alloys, Nickel base alloys, etc., **Non-metals/New materials:** composites, ceramics, polymers, 2D materials/structural materials, electronic materials, etc.
List of experiments	
	Strength of materials: Tensile testing of steel, hardness, torsion, and impact testing. **Metallography:** Microscopic techniques, determination of volume fraction of different phases in material including metals, estimation of grain sizes, study of heat affected regions in welded steel specimen.
Learning Outcomes	1. Students will be able to understand fundamental reason for the choice of engineering materials for various application. 2. Students will be able to suggest appropriate method to improve the mechanical properties of materials as per the requirements. 3. 3. Student will be able to choose the appropriate materials as well as testing method for engineering application.
Assessment Method	Mid Semester Examination, End Semester examination, Class test & quiz, Assignment, Class Performance and Viva, Practical Exam
Texts and References	
	Textbook: 1. William D. Callister, Material science and Engineering and Introduction, Wiley, 2006. 2. V. Raghavan, Materials Science and Engineering, Fifth Edition, Prentice Hall Of India, 2008. 3. G. E. Dieter, Mechanical Metallurgy, McGraw Hill, 1988. 4. W. F. Smith, Materials Science and Engineering (SIE), Tata-McGraw Hill, 2008. **References:** • AVNER, Introduction to Physical Metallurgy, Tata-McGraw Hill, 2008.

Sl. No.	Subject Code	SEMESTER IV	L	T	P	C
1.	ME2201	Kinematics and Dynamics of Mechanisms	3	1	2	5
2.	ME2202	Heat and Mass Transfer	3	1	2	5
3.	ME2203	Mechanics of Solids	3	1	0	4
4.	ME2204	Mechanical Measurements and Instrumentation	3	0	2	4
5.	XX22PQ	IDE-I	3	0	0	3
TOTAL			**15**	**3**	**6**	**21**

Course Name	**Kinematics and Dynamics of Machines**
Course Number	**ME2201**
L-T-P-C	3- 1- 2- 5
Pre-requisites	Dynamics
Semester	Fourth
Learning Mode	Lectures and Practical

Course Learning Objectives

Complies with PLOs 1 and 4.

The objectives of this course are to cover the kinematics and dynamics of planar single degree-of-freedom mechanisms. Specifically, this course will introduce students to the graphical and analytical techniques used for analysis and design of planar mechanism. A semester long course project will be assigned to enable students to apply learned theoretical concepts to real life problems. A side objective of this course will be to introduce MATLAB as a computer tool to solve analysis equations.

Course Content

1. Introduction and course policies
2. Degrees of freedom, elements of kinematic chains, Kutzbach, Gruebler, Grashof's criterion
3. Graphical method of kinematic (displacement, velocity and acceleration) analysis of planar mechanisms
4. Analytical and computer-aided method of kinematic analysis of planar and spatial mechanisms
5. Synthesis of mechanisms
6. Special mechanisms: steering, Hooke's joint
7. Introduction to Cams, classification, terminology of Cams, Design and synthesis of cams by analytical and graphical methods
8. Different gear trains, applications of gear in gear boxes
9. Static and dynamic force analysis, friction in joints
10. Balancing of reciprocating and rotating machines, Gyroscope

List of experiments

a) Learn and apply general mathematical and computer skills to kinematics and dynamics analysis of machine elements including linkages, cams, and gears, within the general machine design context.
b) Apply the theoretical principles to a real-life problem using computer tools.
c) Application of MATLAB software to solve kinematics and dynamics problems.

Learning Outcomes	1. Learn and apply geometrical, analytical and computer skills to kinematics and dynamics analysis of machine elements including linkages, cams, and gears, within the general machine design context. 2. Apply the theoretical principles to a real-life problem using mechanism.
Assessment Method	Mid Semester Examination, End Semester examination, Class test & quiz, Assignment, Class Performance and Viva, Practical Exam

Texts and References

1. J. E. Shigley and J.J. Uicker, Theory of Machines and Mechanisms, McGraw Hill, 1995
2. A. K. Mallik, A. Ghosh, G. Dittrich, Kinematic analysis and synthesis of Mechanisms, CRC, 1994.
3. A. G. Erdman and G. N. Sandor, Mechanism Design, Analysis and Synthesis Volume 1, PHI, Inc., 1997.
5. J. S. Rao and R. V. Dukkipati, Mechanism and Machine Theory, New Age International, 1992.

	6. S. S. Rattan, Theory of Machines, Tata McGraw Hill, 1993. 7. T. Bevan. Theory of Machines, CBS Publishers and Distributors, 1984

Course Name	**Heat and Mass Transfer**
Course Number	**ME2202**
L-T-P-C	3-1-2-5
Pre-requisites	Thermodynamics and Fluid Mechanics, or equivalent
Semester	Fourth
Learning Mode	Lectures and Practical

Course Learning objectives

Complies with PLOs 2 and 4.

1. The student should internalize the meaning of the terminology and physical principles associated with heat and mass transfer processes.
2. The student should be able to delineate pertinent transport phenomena for any process or system involving heat or mass transfer.
3. The student should be able to use requisite inputs for computing heat transfer rates and/or material temperatures.
4. The student should be able to develop representative models of real processes and systems and draw conclusions concerning process/system design or performance analysis.
5. The student should become familiar with design of heat transfer experiments and concerning measurement techniques.

Course Content

Modes of heat transfer:
Conduction: One-dimensional steady conduction, resistance network analogy, fins, two- and three-dimensional steady conduction, one-dimensional unsteady conduction, semi-infinite solids.
Convection: fundamentals, order of magnitude analysis of momentum and energy equations, hydrodynamic and thermal boundary layers, dimensional analysis, free and forced convection, external and internal flows.
Heat exchangers: LMTD and ϵ-NTU methods.
Radiation: Stefan Boltzmann law, Planck's law, emissivity and absorptivity, radiant exchange between black surfaces, view factors, network analysis.
Phase change heat transfer: Boiling and condensation.
Mass transfer: molecular diffusion, Fick's law, binary species

List of experiments

1. Measurement thermal conductivity different materials using composite wall apparatus
2. Determination of the heat transfer coefficient during Forced Convection
3. Determination of the heat transfer coefficient during Natural Convection
4. Determination of Thermal Conductivity of Liquid
5. Phase change heat transfer: (a) Pool boiling
6. Phase change heat transfer: (b) Condensation
7. Performance evaluation of double pipe heat exchanger (a) parallel flow (b) counter flow
8. Performance evaluation of shell-and-tube heat exchanger
9. Emissivity measurement
10. Heat Pipe Demonstration

Learning Outcomes	1. The student should be able to develop representative models of real processes and systems and draw conclusions concerning process/system design or performance analysis. 2. The student should be able to design heat transfer experiments using suitable measurement techniques
Assessment Method	Mid Semester Examination, End Semester examination, Class test & quiz, Assignment, Class Performance and Viva, Practical Exam

Texts and References

	Textbook: 1. Bergman, Theodore L., Frank P. Incropera, David P. DeWitt, and Adrienne S. Lavine. Fundamentals of heat and mass transfer. 7th Edition, John Wiley & Sons, 2011. 2. J.P. Holman, Heat Transfer, 8th Edition, McGraw Hill, 1997. **References:** 1. M.N. Ozisik, Heat Transfer – A basic approach, McGraw Hill, 1985.Bejan, Convection Heat Transfer, 2nd Edition, Interscience, 1994. 2. Bejan, Convection Heat Transfer, 2nd Edition, Interscience, 1994. 3. Y. A. Cengel and Afshin J. Ghajar, Heat and Mass Transfer, 5th Edition, McGraw-Hill, New Delhi, 2020.

Course Name	**Mechanics of Solids**
Course Number	**ME2203**
L-T-P-C	3- 1- 0- 4
Pre-requisites	Engineering Mechanics (ME102)
Semester	Fourth
Learning	Lectures

Course Learning Objectives	
	Complies with PLOs 1 and 4. The objective of this course is to introduce students to the advanced principles and methods of solid mechanics. Design exercises help students to apply theoretical knowledge to practical problems.
Course Content	
	1. Stress as a tensor: stress at point, Cauchy stress tensor, equilibrium equations, analysis of deformation and definition of strain components, compatibility relations: One-to-one deformation mapping, invertibility of deformation gradient, compatibility. 2. Constitutive relations, Theory of failures for isotropic materials. 3. Some properties of Stress and Strain Tensor: Principal stresses and strains, stress and strain invariants. Uniqueness of solution. Plane stress and plane strain problems, Airy's stress function. 4. 2-D problems in polar coordinates: Thin and thick-walled cylinder, Rotating disks and cylinders. 5. Torsion of circular bar, Torsion of non-circular bars: Saint Venant's semi-inverse method, Prandtl stress function. Elliptical and triangular shaft, shaft with cutout, rectangular shaft, hollow shafts, thin tubes narrow rectangular shaft. Membrane analogy. 6. Symmetrical bending, Advanced problem in beam bending: Unsymmetrical bending: pure bending of prismatic and composite beams. Curved beam. Bending of beam with thin profile section - shear flow, determination of shear center. 7. Elastic stability: Buckling of mechanisms, Buckling of straight and bent Beam columns. 8. Energy Methods: Strain energy due to axial, torsion, bending and transverse shear. Comparison of strain energies due to bending and shear. Castigliano's theorem, reciprocity theorem etc. 9. Contact Stresses: Geometry of contact surface, methods of computing contact stress, deflection of bodies in point contact and line contact with normal load. 10. Stress Concentration: Plate with circular hole. 11. Introduction to plate theory (Kirchhoff's theory).
Learning Outcomes	• Develop the analytical skill to calculate stress and strain in an element using suitable theoretical techniques. • Understand different failure theories to predict the failure of solids under multiaxial loading conditions.
Assessment Method	Mid Semester Examination, End Semester examination, Class test & quiz, Assignment, Class Performance and Viva
Texts and References	
	1. S. Timoshenko, Strength of Materials – Parts I and Part II, 3 Ed., CBS Publishers and Distributers, 2004. 2. L.S. Srinath, Advanced Mechanics of Solids, Tata McGraw Hill, 2009. 3. E.P. Popov, Engineering Mechanics of Solids, 2nd Ed, PHI, 1998.

	4. F. P. Beer and E. R. Johnston, J.T. Dewolf, and D.F. Mazurek, Mechanics of Materials, 6th Ed, McGraw Hill Education (India) Pvt. Ltd., 2012. 5. Y.C. Fung, Foundations of Solid Mechanics, Prentice-Hall, 1965. 6. S. C. Crandall, N. C. Dahl, and T. J. Lardner, An Introduction to the Mechanics of Solids, 2e, McGraw Hill, 1999. 7. S. P. Timoshenko and J. N. Goodier, Theory of Elasticity, 3e, McGraw Hill International, 1970.

Course Name	**Mechanical Measurements and Instrumentation**
Course Number	**ME2204**
L-T-P-C	3-0-2-4
Pre-requisites	Nil
Semester	fourth
Learning Mode	Lecture & Practical

Learning Objectives
Course Learning Objectives:
Complies with PLOs 1, 2 and 3.

After completion of this course the student should be able to:

- Recognize different sensors and measurement Methodology in Measurement Systems.
- Should be able to apply measurement Fundamentals in innovative way to apply in varieties of systems.

Project Based Lab

a) select and apply appropriate design methodology.
b) generate a variety of conceptual instruments.
c) demonstration of feasibility of the conceptual design with special emphasis on Mechanical Systems

Course Content	
	Fundamental of Measurement: Elements of a generalized measurement system, standards, and types of signals. Static performance characteristics, Dynamic performance, instrument types - zero, first and second order instruments, transfer function representation, system response to standard input signals - step, ramp, impulse, and frequency response. **Treatment of uncertainties:** Error classification, systematic and random errors, statistical analysis of data, propagation and expression of uncertainties. **Measurement of various physical quantities:** Linear and angular displacement, velocity, force, torque, strain, pressure, flow rate and temperature. Transfer functions of some standard measuring devices. **Metrology:** measurement of angles, threads, surface finish, inspection of straightness, flatness and alignment, gear testing, digital readouts, coordinate measuring machine. **Data Acquisition and processing:** Digital methods, digitization, signal conditioning, interfacing, standard methods of data analysis – quantities obtainable from time series. Fourier spectra, DFT, FFT. Data acquisition parameters - sampling rate, Nyquist sampling frequency, aliasing & leakage errors. **Internet of Things:** Signal recovery, data transmission, IOT components.
List of experiments	
	Linear and Angular Measurements using Vernier, Micrometer, Screw Gauge, Filler gauge, Radius gauge, combination set, Angle measurement using Sine bar, slip gauge and Dial gauge & Error calculation, Thread and Gear tooth measurement, Surface roughness measurement, Use of Sensor kits, Force measurement using dynamometer. Temperature measurement and calibration of thermocouple, Shaft alignment test, Use of accelerometer, Measurements using slip gauge/balls/roller set; Go-NoGo, Telescopic gauge, Depth gauge, Measurements using CMM, Roundness, Scan, C-t-C Distance etc., Nano indentation experiment(DST-FIST facility: No.SR/FST/ET-II/2018/240(C)) Image Processing and visualization using High speed camera. Statistical analysis of measurements in the experiments.
Learning Outcomes	Students after covering this course. (i) Understand the methods of measurement, selection of measuring instruments and standards of measurement. (ii) Identify and learn to use various measuring instruments. (iii) Ability to explain tolerance, limits of size, fits, geometric and position tolerances and gauge design. (iv) Recommend the Quality Control Techniques and Statistical Tools appropriately.

	(v) Ability to analyze the collected data (vi) Develop an ability of problem solving and decision making by identifying and analyzing the cause for variation and recommend suitable corrective actions for quality improvement
Assessment Method	Class test & quiz, Class Performance and Viva, Practical Exam
Texts and References	
	Textbooks 1. E. O. Deobelin, Measurement Systems - Application and Design, Tata McGraw-Hill, 1990. 2. Beckwith T. G., Marangoni, R. D., and Lienhard, J. H., MechanicalmMeasurements, 6e, Addison Wesley, 2020 3. J. Bentley, Principles of measurement systems, 4e, 2004 4. Sudip Misra, Anandarup Mukherjee, Arijit Roy, Introduction to IoT, 2021, Cambridge University Press. 5. E. Doebelin, D. Manik, Measurement Systems, 6th edition ,McGraw Hill Education ; 2017 6. B. C. Nakra and K. K. Chaudhry, Instrumentation Measurement and Analysis, 4th Edition, 2016 **Reference** 1. Figiola, R.S. and Beasley, D.E., Theory and design for mechanical measurements, 6e, John Wiley, 2015. 2. Dally, Riley, and McConnell, Instrumentation for engineering measurements, 2e, John Wiley & Sons, 2010. 3. Doebelin E.O., Engineering Experimentation: Planning, Execution, Reporting, McGraw-Hill, 1995. **4.** Jain R.K., Engineering Metrology, 21e, Khanna Publishers, New Delhi, 1997

Sl. No.	Subject Code	SEMESTER V	L	T	P	C
1.	ME3101	Data Analytics and Machine Learning Tools for Engineers	1	2	1	3.5
2.	ME3102	Design of Machine Elements	3	0	3	4.5
3.	ME3103	Manufacturing Technology- I	3	0	2	4
4.	ME3104	Engineering Software Laboratory	1	0	3	2.5
5.	ME3105	Numerical Methods for Engineers	3	0	0	3
6.	XX31PQ	IDE-II	3	0	0	3
TOTAL			**14**	**2**	**9**	**20.5**

Course Name	Data Analytics and Machine Learning Tools for Engineers
Course Number	ME 3101
L-T-P-C	1-2-1-3.5
Pre-requisites	Mechanical Measurements and Instrumentation
Semester	Fifth
Learning Mode	Lecture and Practical

Course objectives

Complies with PLO 4.

1. To expose students to the implementation of data analysis strategies and tools used therein
2. To expose students to the basics of modern machine learning tools for mechanical engineering applications

Course Content

Data Analytics:

Data: Vectors and Arrays, managing data, Statistical Visualization of data, Evaluating Data: Central Tendency, Measure of dispersion

Distributions: Normal (Gaussian and Poisson) Distribution, Exponential Distribution, Weibull Distribution, Chi-square, Distribution Fitting, Confidence interval

Random Variates: Pseudorandom, Uniform and Normal, Quasi-Random Sequence Halton

Regression: Linear regression models, Fitting linear models to data, Evaluating the fit

Optimization tools: Specifying the objective function, specifying constraints, selecting optimization methodology, evaluating results, global optimization tools

Analysis of experimental data: quality of measurement, types of errors, error propagation

Machine Learning:

Fundamentals of Machine Learning, Supervised learning techniques, Overfitting/Confronting overfitting, Classification and Regression, Neural Networks, Training of Multi-Layer Neural Network, Neural Network and Classifications, Deep learning, Convolutional Neural Network, Introduction to unsupervised learning techniques, K-means clustering, K-nearest neighbours, Case-Studies showing use of Machine Learning in Mechanical Engineering such as Acoustics, CFD, Robotics, Metrology

Learning Outcome

By the end of this course, mechanical engineering undergraduate students should be able to:

- Appreciate the use of data analytics and machine learning tools to solve mechanical engineering problems wherein analytical solutions are difficult to obtain
- Appreciate what is involved in developing models for a given data set
- Understand a wide variety of learning algorithms
- Understand how to evaluate models generated from data

Apply the models learnt to relevant mechanical engineering problems, optimize the models learned, and report on the expected accuracy that can be achieved by applying the models

Assessment Method

Mid Semester Examination, End Semester examination, Class test & quiz, Assignment, Class Performance and Viva

Texts and References

1. Introduction to the Theory of Statistics by A.M. Mood, F.A. Graybill and D.C. Boes, 2017
2. Statistics and Machine Learning Toolbox, User Guide, MATLAB R2021b
3. MATLAB Deep Learning with Machine Learning, Neural Network and Artificial Intelligence by Phil Klim, Apress 2017
4. Deep Learning by Ian Goodfellow, Yoshua Bengio and Aaron Courville, MIT Press, 2016
5. Christopher Bishop. Pattern Recognition and Machine Learning. ISBN 0387310738, 2010.

Course Name	**Design of Machine Elements**
Course Number	**ME3102**
L-T-P-C	3- 0- 3- 4.5
Pre-requisites	Mechanics of Solids
Semester	Fifth
Learning Mode	Lectures and Practical

Course objectives

Complies with PLOs 1 and 4.

1. To develop the basic understanding of machine design criteria
2. To develop analytical skills to deal with various types of machine element design problems.
3. Laboratory sessions are designed for developing software and experimental skills

Course Content

Limits, fits, and tolerances, Principles of mechanical design; Factor of safety, strength, rigidity, fracture, wear, and material considerations; Stress concentrations; Design for fatigue; Design of bolted, and welded joints; Shafts; Keys; Clutches; Brakes; Springs; Gears; bearing and lubrication.

List of experiments/Laboratory Session

1. Machine Drawing: Assembly and Part drawings, Solid modeling etc.
2. Design of gear box and sub-components (shafts, bearings, bolts, housing, coupling, etc.);
3. IC engine components; Screw jack; Shaft coupling;
4. Computer Aided Design
5. Two Tribology experiments

Learning Outcomes

1. Develop analytical and computer skills to design a simple engineering element
2. Understand the static and dynamic failure principles of solid and apply them in engineering element design

Assessment Method: Mid Semester Examination, End Semester examination, Class test & quiz, Assignment, Class Performance and Viva, Practical Exam

Texts and References

1. J. E. Shigley, Mechanical Engineering Design, McGraw Hill, 1989.
2. Design Data, PSG Tech, Coimbatore, 1995
3. M. F. Spotts, Design of Machine Elements, 6th ed., Prentice Hall, 1985
4. A. H. Burr and J. B. Cheatham, Mechanical Analysis and Design, 2nd ed., Prentice Hall,1997.
5. Machine Drawing by N D Bhatt

Course Name	**Manufacturing Technology - I**
Course Number	**ME3103**
L-T-P-C	3-0-2-4
Pre-requisites	Nil
Semester	Fifth
Learning Mode	Lectures & Practical

Course Learning objectives

Complies with PLOs 3 and 4.
This course aims to impart (a) the fundamental aspects of casting, welding, forming processes and powder metallurgy (b) to train the students with the analytical, practical, and problem-solving skills related to above manufacturing processes.

Course Content

Module 1: Foundry
Moulding materials and their requirements: types, composition and properties of molding sand, sand testing; Patterns: types of patterns, pattern allowances; Casting processes: sand casting, shell moulding, sodium silicate moulding, no bake moulding, gravity die, pressure die casting, investment casting, centrifugal casting, continuous casting, thin roll casting, plaster moulding, ceramic shell moulding; Solidification of casting: nucleation, grain growth, flow properties of molten metal, mechanism of heat transfer, phase change, solidification of binary alloy, directional and progressive solidification; Gating and risering systems: casting terminology, design of flask, sprue, runner and gating system, type of gate, time of solidification, chill and chaplet, CFR; Casting defects and their remedies.

Module 2: Joining processes
Physics, principle of operation and process parameters: Fusion welding (MMAW, MIG, TIG, SAW, power characteristics, seam, spot, projection, electroslag, Thermit and gas welding), Solid-state welding (adhesive, diffusion, friction, ultrasonic and explosive welding), Solid-liquid state welding (brazing and soldering), Unconventional welding (EBW, LBW etc.); Relative advantages and limitations of joining processes; Welding defects, inspection and testing.

Module 3: Fundamentals of metal forming
Introduction to plastic deformation of materials and related properties; various bulk deformation processes (forging, drawing, extrusion, rolling, swaging); load analysis of various bulk deformation processes by slab method; forming defects; sheet metal working (blanking & punching, bending, deep drawing, spinning, load analysis);

Module 4: Powder metallurgy
Basic principles, powder properties and production, blending and mixing, compaction, sintering, post-sintering treatment, shape factor and aspect ratio, advantages and limitations of the process, applications.

List of experiments

1. Foundry: Testing of Moulding sand and Core sand, Preparation of one casting (Aluminum or cast iron), Testing's (Destructive and Non-destructive)
2. Joining: Tungsten inert gas welding, Metal Inert Gas welding, and Friction stir welding, Determination of weld thermal cycle, cooling rate, Mechanical and Microstructural characterization of welds
3. Metal Forming: Estimation of force in Deep drawing, Extrusion, Open die forging
4. Powder Metallurgy: Metal powders preparation, Evaluate Green Density as well as Strength Characteristics (hardness) of Cold-compacted and sintered (Conventional) powder, Data Analysis, Destructive and Non-destructive tests

Learning Outcomes

1. The main objective of the course is to make the student familiar with the importance of manufacturing sciences in the day-to-day life, and to study the basic manufacturing processes like casting, metal forming, welding, and powder metallurgy.

	2. To trained the graduates with the analytical, practical and problem-solving skills related to the conventional manufacturing processes.
Assessment Method	Mid Semester Examination, End Semester examination, Class test & quiz, Assignment, Class Performance and Viva
Texts and References	
	Textbook: 1. Fundamental of Modem Manufacturing: Materials, Processes and Systems, Mikell P.Groover 2. Fundamental of Manufacturing, G. K. Lal & S. K. Choudhury 3. Materials &Processes in Manufacturing, E. P. DeGarmo, J. T. Black and Kohser 4. Manufacturing Engineering &Technology, S. Kalpakjian, S.R. Schmid

Course Name	**Engineering Software Laboratory**
Course Number	**ME3104**
L-T-P-C	1-0-3-2.5
Pre-requisites	Nil
Semester	Fifth
Learning Mode	Lectures and Practical

Course Learning Objectives:
Complies with PLOs 1-4.
Exposure to industrial software used in Mechanical Engineering practices.

Course Content	
	CAD: 2D and 3D geometric transformation, Curves and surfaces in CAD **FEM:** Solid model creation, different types of elements, chunking of model, meshing, mesh quality, different kinds of analysis: static, dynamic, transient, thermal, electromagnetic, acoustics, sub-structuring and condensation, Error and convergence. **CFD:** Different types of CFD techniques, various stages of CFD techniques (i) preprocessor: governing equations, boundary conditions, grid generation, different discretization techniques (ii) processor: solution schemes, different solvers (iii) post-processing: analysis of results, validation, grid independent studies etc. Developing codes using commercial software for solving few problems of laminar and turbulent flow with heat transfer applications. Engineering softwares related to CAD/CAM, FEM, CFD, with both GUI and script like languages, are to be used for laboratory assignments.
Learning outcomes	At the end of the course, students will be able to use the industrial software for simulating industrial and research problems related to solid and fluid mechanics. A mature understanding of various numerical techniques and their advantages and disadvantages will develop with respect to the software used in the class.
Assessment Method	Class test & quiz, Assignment (hands-on exercises using software), Class Performance and Viva, Practical Exam

Texts and References

Textbook:

1. J. N. Reddy, "An Introduction to Finite Element Methods", 3rd Ed., Tata McGraw-Hill, 2005.
2. D. F. Rogers and J. A. Adams, "Mathematical Elements for Computer Graphics", McGraw-Hill, 1990
3. M. Groover and E. Zimmers, "CAD/CAM: Computer-Aided Design and Manufacturing", Pearson Education, 2009.
4. J. D. Anderson, "Computational Fluid Dynamics", McGraw-Hill Inc. (1995).

Course Name	Numerical Methods for Engineers
Course Number	ME3105
L-T-P-C	3-0-0-3
Pre-requisites	Nil
Semester	Fifth
Learning Mode	Lectures

Course objectives

Complies with PLOs 1-4.

1. To expose students to a range of topics related to solving mechanical engineering problems using computational techniques.
2. To expose students to the basics of numerical methods for solving governing equations related to engineering problems.
3. To utilize software tools for solving numerical problems related to this course

Course Content

1. **Introduction & Approximation:**
   Motivation and Application, Accuracy and precision; Truncation and round-off errors; Binary Number System; Error propagation
2. **Linear Systems and Equations: Direct Methods**
   Matrix representation; Cramer's rule; Gauss Elimination; Matrix Inversion; LU Decomposition;
3. **Linear Systems and Equations: Indirect Methods**
   Iterative Methods; Relaxation Methods; Eigen Values
4. **Algebraic Equations:**
   Introduction to Algebraic Equations, Bracketing methods: Bisection, Reguli-Falsi;
   Algebraic Equations: Open Methods, Secant; Fixed point iteration; Newton-Raphson; Multivariate Newton's method
5. **Numerical Differentiation:**
   Numerical differentiation; error analysis; higher order formulae
6. **Numerical Integration**:
   Trapezoidal rules; Simpson's rules; Gauss Quadrature
7. **Regression:**
   Linear regression; Least squares; Total Least Squares
8. **Interpolation and Curve Fitting:**
   Interpolation; Newton's Difference Formulae; Cubic Splines
9. **ODEs: Initial Value Problems:**
   Introduction to ODE-IVP, Euler's methods; Runge-Kutta methods; Predictor-corrector methods.
10. **ODE-IVP (Part-2)**
    Extension to multi-variable systems; Adaptive step size; Stiff ODEs
11. **ODEs: Boundary Value Problems:**
    Shooting method; Finite differences; Over/Under Relaxation (SOR)

Learning Outcomes:

By the end of this course, mechanical engineering undergraduate students should be able to:

- Understand how to apply numerical methods to solve problems related to mechanical engineering using software's.
- Solve ordinary differential equations (ODEs) and partial differential equations (PDEs) using numerical methods.
- Solve problems and write programs related to engineering problems with respect to mechanical engineering.
- Find roots of equations

Assessment Method
Mid Semester Examination, End Semester examination, Class test & quiz, Assignment, Class Performance and Viva

Texts and References

1. Numerical Methods in Engineering: M. Salvadori.
2. Applied Numerical Methods: B. Carnahan.
3. Applied Numerical Analysis: C.F. Gerald and P.O. Wheatley.
4. Numerical Mathematics & Computing: W. Cheney and D. Kincaid.
5. Applied Partial Differential Equations: Paul DuChateau and David Zachmann.
6. Partial Differential Equations for Scientists and Engineers: Stanley J. Farlow.
7. Numerical Methods for Partial Differential Equations: William F. Ames.
8. Numerical Methods for Elliptic and Parabolic Partial Differential Equations: John R Levison, Peter, Knabner, Lutz Angermann.
9. Numerical Methods for Engineers by Steven Chapra, and Raymond Canale.

Sl. No.	Subject Code	SEMESTER VI	L	T	P	C
1.	ME3201	Applied Thermodynamics and Turbomachinery	3	1	2	5
2.	ME3202	System Dynamics and Control	3	1	2	5
3.	ME3203	Manufacturing Technology -II	3	0	3	4.5
4.	ME3204	Industrial Engineering and Operations Research	3	1	0	4
5.	ME3205	Technical Writing and Presentations	0	0	4	2
TOTAL			**12**	**3**	**11**	**20.5**

Course Name	**Applied Thermodynamics and Turbomachinery**
Course Number	**ME3201**
L-T-P-C	3- 1- 2- 5
Pre-requisites	Thermodynamics and Fluid Mechanics, or equivalent
Semester	Sixth
Learning Mode	Lectures and practical

Course Learning objectives

Complies with PLOs 2 and 4.

1. To develop a good understanding of the various power and refrigeration cycles,
2. To understand basic fundamentals of turbomachinery and their working principles and thermodynamic design
3. To develop knowledge on designing different components of power and refrigeration cycles

Course Content

Vapour power cycles: Rankine cycle, reheat cycle, regenerative cycle, cogeneration; Steam turbine: impulse and reaction stage, degree of reaction, velocity triangle, velocity and pressure compounding, efficiencies, Steam nozzles.
Refrigeration cycles: Properties of Refrigerants, Carnot refrigeration cycle, vapor compression cycle, Psychrometry.
Gas power cycles: Gas turbine cycle, intercooling, reheating, regeneration, closed cycles, optimal performance of various cycles, combined gas and steam cycles; Axial-flow gas turbine; Jet propulsion: turbojet, turbofan.
I.C. Engines: Classification - SI, CI, two-stroke, four-stroke etc., operating characteristics - mean effective pressure, torque and power, efficiencies, specific fuel consumption etc., air standard cycles - Otto, Diesel and dual, real air-fuel engine cycles, combustion in S.I. and C.I. engines, Air and fuel injection system, engine emissions.
Compressors: Reciprocating Air Compressors, Centrifugal and Axial-flow compressors.
Fluid Machines: Pelton-wheel, Francis and Kaplan turbines, centrifugal and reciprocating pumps.

List of experiments

1. Impact of jet
2. Performance of Pelton turbine
3. Performance of Axial Flow turbine
4. Performance of Francis turbine
5. Performance evaluation of centrifugal pump
6. Performance evaluation of reciprocating pump
7. Refrigeration test rig
8. Air conditioning test rig
9. Performance of 4-stroke petrol & diesel engine
10. Exhaust gas analyzer

Learning Outcomes

1. Students will be able to think critically for solving relevant practical problems
2. Students will develop analytical skills for designing different components of gas and refrigerant cycles
3. Students will be able to come up with innovative ideas on applications of existing thermodynamics cycles

Assessment Method: Mid Semester Examination, End Semester examination, Class test & quiz, Assignment, Class Performance and Viva, Practical Exam

Texts and References

Textbook:

1. M MEl Wakil, Power Plant Technology, McGraw Hill Education, 1e, 2017.
2. P K Nag, Powerplant Engineering, Tata McGraw Hill, 4e, 2017.

	3. H I H Saravanamuttoo, G F C Rogers and H. Cohen, Gas Turbine Theory 7e, Pearson, 2019 4. W WPulkrabek, Engineering Fundamentals of the Internal Combustion Engine, PHI, 2002. 5. T. D. Eastop and A. McConkey, 2009, Applied Thermodynamics for Engineering Technologists, 5th Ed. **References:** 1. G. F.C. Rogers and Y R Mayhew, 2009, Engineering Thermodynamics Work and Heat Transfer, 4th Ed., Pearson Education. 2. M J Moran and H N Shapiro, Fundamentals of Engineering Thermodynamics 6e, John Wiley, 2007. 3. Arora C P, Refrigeration and Air Conditioning, McGraw Hill, 4e, 2021 4. C R Fergusan and A T Kirkpatrick, Internal Combustion Engines: Applied Thermosciences, 3e, John Wiley & Sons, 2016.

Course Name	**System Dynamics and Control**
Course Number	**ME3202**
L-T-P-C	3-1-2-5
Pre-requisites	Dynamics (ME 207)
Semester	Six
Learning Mode	Lectures and Practical

Course Learning Objectives:

Complies with PLOs 1 and 4.

1. The objective of this course is to introduce students to the theory and techniques for system dynamics and control so as to ensure the system design achieves desirable properties (e.g., stability, performance).
2. The course will introduce students to mathematical modeling of linear time invariant dynamic systems. In particular, the course will cover multi-degree of freedom systems with multiple components. The response of these systems to inputs and initial conditions will be analyzed.
3. Systems obtained as interconnections (e.g., feedback) of two or more other systems will be covered. The course will also introduce the students to the concepts of stability. Various techniques for determination of stability will be covered.
4. Techniques of controller design are also covered in this course. The course comprises complementary laboratory and tutorial sessions.

Course Content	
	Fundamental of System- zero, first and second order system, application to free vibration, Frequency and time domain response. **Transfer function**- application to SDOF forced vibration, whirling of rotating shaft and critical speeds of shafts, vibration isolation, Transfer functions of some standard motion sensor like accelerometer, seismometer and velocity pick up. **Feedback System**- Block diagram and signal flow representation, state space model. Introduction to PID controller, Application to common control system. **Stability and analysis of Dynamical System**- Routh-Hurwitz stability criterion, relative stability, Root-locus method, Bode diagrams, Nyquist stability criterion, PI, PD, and PID controllers; Lead, lag, and lag-lead compensators, Application to common engineering problems. **Introduction to Passive two and multi-DOF system**- normal mode vibration, coordinate coupling, forced harmonic vibration, vibration absorber, flexibility matrix, stiffness matrix, reciprocity theorem, eigenvalues and eigenvectors, orthogonal properties of eigenvectors, modal matrix, Normal mode summation. **Introduction to State Space Control:** Controllability, observability and design.
List of experiments	
	(1) Cantilever Beam damping estimation (2) Cantilever Beam system identification (3) Air Track mass spring vibratory system (4) Matlab primer (5) Dynamics and Control of magnetic levitation system (6) System Identification of Black box (7) Control of servomotor (8) Control of inverted pendulum (9) NI data acquisition via a few basic sensors like a potentiometer, optical encoder, and strain gauge (10) Matlab control toolbox and simulink (11) Programmable Logic Controller Ladder Logic
Learning Outcomes	After completing this course, the students will be able to 1. develop mathematical models of single and multi degree of freedom dynamic systems, 2. determine stability of a given linear time-invariant dynamical system, 3. design feedback PID control systems, 4. appreciate practical aspects of dynamics and control via laboratory experiments on sensors and instrumentation.
Assessment Method	Mid Semester Examination, End Semester examination, Class test & quiz, Assignment, Class Performance and Viva, Practical Exam
Texts and References	

	1. W. T. Thomsom and Dahleh, M. D., Theory of Vibration with Applications, 5th ed., Pearson Education, 1999. 2. Doebelin E.O., Measurement systems- Applications and Design, 4e, Tata McGraw-Hill, 1990 3. K Ogata, Modern Control Engineering, 4th ed, Pearson Education Asia, 2002. 4. B C Kuo and F. Golnaraghi, Automatic Control Systems, 8th ed, John Wiley (students ed.), 2002. 5. M Gopal, Control Systems: Principles and Design, 2nd ed, TMH, 2002. 6. M Gopal, Modern Control System Theory, 2nd ed., New Age International, 1993. 7. R. C. Dorf and R. H. Bishop, Modern Control Systems, 8th ed., Addison Wesley, 1998. 8. P. Belanger, Control Engineering: Amodern approach, Saunders College Publishing, 1995.

Course Name	**Manufacturing Technology - II**
Course Number	**ME3203**
L-T-P-C	3-0-3-4.5
Pre-requisites	Nil
Semester	Sixth
Learning Mode	Lectures and Practical

Course Learning objectives

Complies with PLOs 3 and 4.

1. Introduce the fundamental science and engineering of conventional and non-conventional machining processes.
2. Introduce the standard testing procedures to evaluate the machining performance.

Course Content

Module-I: Fundamentals of metal cutting

Geometry of single point cutting tool (ORS, ASA etc.); orthogonal cutting; mechanism of chip formation; Analytical and experimental determination of cutting forces (Merchant's circle diagram); cutting temperature (causes, effect, assessment and control); machinability; tool materials; failure of cutting tools and tool life; economics of metal cutting

Module-II: Machine tools

Generatrix and directrix; classification of machine tools; setting and operations on machines: lathe, shaper, planer, milling, drilling, broaching, slotting, grinding, gear cutting machines; mechanism: thread cutting, pawl and ratchet wheel, quick return, indexing etc.; Finishing: honing, lapping; CNC machine tools

Module-III: Tooling

Principle of location and clamping; principles of design of jigs and fixtures

Module-IV: Unconventional machining

USM, AJM, AWJM, ECM, EDM, LBM, EBM: principle of operation, process parameters, material removal rate, advantages and limitations.

Module-V: Manufacturing with plastic materials

Properties of plastics; plastic materials; processing technology: extrusion, injection moulding, blow moulding, thermoforming, etc, 3D printing of polymers and plastic materials

List of experiments

Fabrication of single point cutting tool, Resharpening of drill Bit, Fabrication of helical gear, Experimental determination of cutting forces in turning, with or without cutting fluid, Experimental determination of cutting temperatures in turning with or without cutting fluid, CAD/CAM – Creo Manufacturing Module/CNC milling, Effect of USM parameters on Material removal rate(MRR), Surface roughness (SR) and Dimensional Accuracy (Taper, overcut), Effect of EDM parameters on Material removal rate(MRR), Surface roughness (SR) and Dimensional Accuracy (Taper, overcut), Experimentation on WEDM/Surface grinding , 3D printing.

Learning Outcomes

1. Students will be able to understand the fundamental reason for the choice of machining processes for making various product
2. Students will be able to choose the appropriate machining process, operation for building engineering components economically.
3. Students will be able to characterize the machining performance of materials
4. Student will be able to choose the appropriate machine tool do get a job done.

Assessment Method

Mid Semester Examination, End Semester examination, Class test & quiz, Assignment, Class Performance and Viva, Practical Exam

Texts and References

Textbook:

1. M. C. Shaw, Metal Cutting, Tata McGraw Hill, New Delhi, 2004.
2. S. Kalpakjain, S. R. Schmid, Manufacturing Processes for Engineering Materials, fifth edition, Pearson.
3. A. Ghosh and A. K. Malik, Manufacturing Science, East West Press, 2010.

	4. P.N Rao, Manufacturing Technology, 4e, volume 1, McGraw Hill Education. **References:** 1. G. Boothroyd and W. A. Knight, Fundamentals of Machining and Machine Tools, CRC-Taylor and Francis, 2006.

Course Name	**Industrial Engineering and Operations Research**
Course Number	**ME3204**
L-T-P-C	3-1-0-4
Pre-requisites	Nil
Semester	Sixth
Learning Mode	Lectures

Course Learning Objectives
Complies with PLO 4.
The objectives are to produce graduates who: Contribute to the success of companies through
effective problem solving. Design, develop, implement, and improve integrated systems that include people, materials, information, equipment, and environments.
1. To impart knowledge in concept and tools of OR
2. To understand mathematical models used in Operations Research
3. To apply these techniques constructively to make effective business decisions

Introduction: history, method, Organisation: Theory, Principle, structure
Product Design and Development: Principles of product design, tolerance design; Quality and cost considerations; Product life cycle; Standardization, simplification, diversification
Engineering Economy and Costing: Elementary cost accounting and methods of depreciation; Break-even analysis; elasticity of demand, break even analysis. Job evaluation: methods, wage payments plan, incentive scheme
Production planning and control: Forecasting techniques – causal and time series models, moving average, exponential smoothing, trend and seasonality;Aggregate production planning;Master production scheduling; MRP, MRP-II, JIT, CIM and ERP; Routing, scheduling and priority dispatching; Push and pull production systems,concepts of Lean and JIT manufacturing systems; Inventory – functions, costs, classifications, deterministic inventory models- Objective, type (ABC and VED analysis), EOQ and EPQ (case study), quantity discount; Perpetual and periodic inventory control systems

Work System Design: Taylor's scientific management, Gilbreths's contributions; Productivity – concepts and measurements; Method study, Micro-motion study, Principles of motion economy; Work measurement – cycle time, learning curve, time study, Work sampling, charting technique, PMTS; Ergonomics- Objective, History, system components, Type (physical, cognitive, work environment, operational safety health).; Job evaluation and merit rating.
Facility Design: Facility location factors and evaluation of alternate locations; Types of plant layout and their evaluation, layout planning and design, line balancing, Chart and diagram: process analysis, operation chart, process chart, flow diagram, activity chart, Assembly line balancing;
Reliability and Maintenance: Reliability, availability and maintainability; Distribution of failure and repair times; Determination of MTBF and MTTR, Reliability models; Determination of system reliability; Preventive and predictive maintenance and replacement, Total productive maintenance.
Quality engineering: Quality objectives, quality dimension, Quality control – Quality Assurance Quality costs, Quality loss function, Quality gurus and their philosophies, control charts for variables and attributes, Process capability studies, Six sigma; Total quality management; Quality assurance and certification - ISO 9000, ISO14000, SQC and SPC
Operation Research: Introduction, Linear Programming: Graphical, Simplex, Dual Simplex, Sensitivity analysis, Transportation, Assignment, Integer Programming: Branch and Bound technique, Network Model: PERT and CPM, Spanning Tree (Prism and Kruskal algorithm), Markovian queuing models

Learning Outcomes	1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics. 2. Ability to design, develop, implement, and improve integrated systems that include people, materials, information, equipment and energy. 3. An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives 4. An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors. 5. Identify and develop operational research models from the verbal description of the real system 6. Understand the mathematical tools that are needed to solve optimisation problems. 7. Use mathematical software to solve the proposed models. 8. Develop a report that describes the model and the solving technique, analyze the results and propose recommendations in language understandable to the decision-making processes in Management Engineering.
Assessment method	Mid Semester Examination, End Semester examination, Class test & quiz, Assignment, Class Performance and Viva
Texts and References	
	Textbook: 1. S L Narasimhan, D W McLeavey, P J Billington, Production, Planning and Inventory Control, Prentice Hall, New Edition 2. N V S Raju, Industrial Engineering and Management, CENAGE , New Edition 3. A Muhlemann, J Oakland and K Lockyer, Productions and Operations Management, Macmillan, New Edition 4. H A Taha, Operations Research - An Introduction, Prentice Hall of India, New Edition **References:** 1. J K Sharma, Operations Research, Macmillan, New Edition 2. O. P Khana, Industrial Engineering, Dhanpat Rai, New Edition 3. J L Riggs, Production Systems: Planning, Analysis and Control, Wiley, New Edition

Course Name	Technical Writing and Presentations
Course Number	ME3205
L-T-P-C	0-0-4-2
Pre-requisites	Nil
Semester	Sixth
Learning Mode	Practical

Course objectives

Complies with PLO 4.

1. To train students for technical presentation which includes making PPT slides and verbal communication during presentations.
2. To train students for technical writing which includes writing an abstract, extended abstracts, and full paper.

Course Content

Module 1: Technical Writing

Writing an abstract

- Standard formats and templates
- Writing effective titles

Writing an extended abstract

- Standard formats and templates
- Writing effective titles, abstracts, introductions, and conclusions
- Organizing content with headings and subheadings
- Referencing and citation standards
- Writing drafts
- Techniques for clear and concise writing
- Avoiding common pitfalls in technical writing
- Editing for grammar, style, and accuracy

Module 2: Technical Presentations

Preparing for Technical Presentations

- Audience analysis for presentations
- Structuring a technical presentation
- Designing effective presentation slides

Presentation Delivery

- Public speaking skills for technical presentations
- Handling questions and feedback
- Strategies for engaging the audience

Module 3: Technical Writing on a specialized scientific Topic

- Students select a specific topic write abstract and further extended abstract on the same topic.
- Abstract and extended abstracts are evaluated and students are provided with comments and suggestions for improvement of the write-up.

Module 4: Technical presentation on a specialized scientific Topic

- Students prepare a presentation on a specialized topic and present in the class.
- Based on the presentation, students are evaluated and advised for improving in slide preparation as well as delivery.

Learning Outcomes:

By the end of this course, the student should be able to:

- Understand the principles of technical writing and its various forms.
- Develop and organize technical documents effectively.
- Master the use of visuals and data in technical communication.
- Create professional presentations tailored to technical content.
- Present technical information clearly and confidently to diverse audiences.
- Review and edit technical documents for clarity, coherence, and correctness

Assessment Method
Ongoing Evaluation for each section through the semester: Abstract and Extended Abstract; and Technical Presentations

Texts and References

Books:

- "Technical Communication" by Mike Markel and Stuart A. Selber
- "The Elements of Technical Writing" by Gary Blake and Robert W. Bly
- "Writing and Speaking in the Technology Professions: A Practical Guide" by David F. Beer and David A. McMurrey

Online Resources:

- Purdue OWL: Technical Writing
- IEEE Author Center
- Society for Technical Communication (STC) website

Sl. No.	Subject Code	SEMESTER VII	L	T	P	C
1.	ME41XX	Departmental Elective-I	3	0	0	3
2.	ME41XX	Departmental Elective- II	3	0	0	3
3.	XX41PQ	IDE-III	3	0	0	3
4.	HS41PQ	HSS Elective-II	3	0	0	3
5.	ME4198	Summer Internship*	0	0	12	3
6.	ME4199	Project – I	0	0	12	6
TOTAL			**12**	**0**	**24**	**21**

Sl. No.	Subject Code	Department Electives - I	L	T	P	C
1.	ME4101	Tribology and Surface Engineering	3	0	0	3
2.	ME4102	Basics of Computational Fluid Dynamics	3	0	0	3
3.	ME4103	Industrial Automation	3	0	0	3

Course Number	**ME4101**
Course Credit	L-T-P-C : 3-0-0-3
Course Title	**Tribology and Surface Engineering**
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 1 and 4 After attending the class, the students will be able to understand 1. The primary cause of friction and wear in various tribological contact 2. The importance of lubrication and regimes of lubrication in engineering surfaces 3. The use of surface treatment and suitable coatings for the improvement of tribological characteristic 4. The need for different characterization techniques to evaluate the performance of engineering surfaces.
Course Description	This course is designed to understand theories of friction, wear, and lubrication, model basic tribological processes, and understand the influence of surface engineering on tribological contact. Prerequisite: NIL
Course Outline	Introduction – Significance of tribology, history of tribology, Economic Benefits, Interdisciplinary Approach, Need of surface engineering. Surface characteristics – Topography and microstructure of surfaces, Origin of roughness, Measurement of surface characteristics, Roughness parameters, Mechanics of solid surfaces. Friction – Laws of friction, Adhesion theory, Abrasion theory, Stick-slip motion, Rolling friction, Tribological tests. Wear – Adhesive Wear, Abrasive Wear, Delamination Wear, Fretting Wear, Erosive Wear, Corrosive Wear, Oxidative Wear, Wear Mechanism Maps. Lubrication and Lubricants – Boundary Lubrication, Mixed Lubrication, Elasto-Hydrodynamic Lubrication, Hydrodynamic Lubrication, Types and Properties of Lubricants, Lubricants Additives. Applications/ Case study – Sliding contacts, Rolling contacts, Bearing design, Selection of surface treatment/ soft or hard coatings/ surface textures
Learning Outcome	Develop an understanding of the characteristics of tribological contact of moving engineering components and ways to prevent failure or increase the life of such components.
Assessment Method	Assignments, Quiz, Mid-semester and End-semester exams

Suggested Readings:

Text Books:

[1] R.D. Arnell, P.B. Davies, J. Halling, T.L. Whomes, Tribology: principles and design applications, Macmillan Education Ltd, First edition 1991.
[2] B. Bhushan, Principles and Applications of Tribology, John Wiley, second edition, 2013.
[3] A. Cameron, Basic Lubrication Theory, E. Horwood, Halsted Press, 1976.
[4] I. Hutchings, P. Shipway, Tribology: friction and wear of engineering materials, Butterworth-heinemann, 2nd Edition, 2017.
[5] G. Stachowiak, A.W. Batchelor, Engineering tribology, Butterworth-heinemann, Fourth edition, 2013.
[6] B. J. Hamrock, B. O. Jacobson, S. R. Schmid, Fundamentals of Machine Elements, McGraw-Hill Inc., 1998.
[7] K. S. Edwards, R. B. McKee, Fundamentals of Mechanical Component Design, McGraw-Hill Inc., 1991.

Course Name	**Basics of Computational Fluid Dynamics**
Course Number	**ME4102**
L-T-P-C	3-0-0-3
Pre-requisites	Undergraduate Fluid Mechanics and Heat Transfer course
Learning Mode	Class room lecture
Course objectives	
Complies with PLOs 2 and 4	

- This course is designed to fulfil the basic concepts of computational fluid dynamics. The course first discusses the general background required for understanding the various numerical methods or discretization techniques involved in CFD. It is followed by a detailed understanding of the two of the popular discretization methods – Finite Difference Method (FDM) and Finite Volume Method (FVM).

Course Content

Concept of Computational Fluid Dynamics: Different techniques of solving fluid dynamics problems, their merits and demerits, governing equations of fluid dynamics and boundary conditions, classification of partial differential equations and their physical behavior, Navier-Stokes equations for Newtonian fluid flow, computational fluid dynamics (CFD) techniques, different steps in CFD techniques, criteria and essentialities of good CFD techniques.

Finite Difference Method (FDM): Application of FDM to model problems, steady and unsteady problems, implicit and explicit approaches, errors and stability analysis, direct and iterative solvers.

Finite Volume Method (FVM): FVM for diffusion, convection-diffusion problem, different discretization schemes, FVM for unsteady problems. SIMPLE family FVM for solving Navier-Stokes equation

Learning Outcomes:

After attending this course, the following outcomes are expected:

1. Ability to classify the partial differential equations involved in fluid mechanics and heat flow and understanding of their physical behaviour.
2. Ability to write CFD codes for the various algorithms covered in this course.

Assessment Method

- Quiz, mid and end semester examinations, Coding Assignments, Viva

Texts and References

Text Books:

1. J. D. Anderson, “Computational Fluid Dynamics”, McGraw-Hill Inc. (New Edition).
2. S. V. Patankar, “Numerical Heat Transfer and Fluid Flow”, Hemisphere Pub. (New Edition)
3. D. A. Anderson, J. C. Tannehill and R. H. Pletcher, “Computational Fluid Mechanics And Heat Transfer”, Hemisphere Pub. (New Edition)
4. M. Peric and J. H. Ferziger, “Computational Methods for Fluid Dynamics”, Springer (New Edition).
5. H. K. Versteeg and W. Malalaskera, “An Introduction to Computational Fluid Dynamics”, Dorling Kindersley (India) Pvt. Ltd. (New Edition).

Reference Books:

1. C. Hirsch, “Numerical Computation of Internal and External Flows”, ButterworthHeinemann, (New Edition).
2. K. Muralidhar, and T. Sundarajan, “Computational Fluid Flow and Heat Transfer”, Narosa (New Edition)
3. A. Sharma, “Introduction to Computational Fluid Dynamics Development, Application and Analysis”, Ane Books, 1st edition 2016

Course Name	Industrial Automation
Course Number	**ME4103**
L-T-P-C	3-0-0-3
Pre-requisites	Nil
Learning Mode	Class room lecture

Course objectives

Complies with PLOs 3 and 4

- To gain fundamental principles of industrial automation approaches.
- To understand the various pneumatic, hydraulic actuators, valves, sensors.
- To gain concept of pneumatic, hydraulic and electo-pneumatic/-hydraulic circuit design for different activities/operations.
- To gain concepts of automatic transfer lines, assembly systems.

Course Content

Fundamental concepts and types of automation, Various automation strategies.

Introduction to Pneumatics and Hydraulics, Electro-pneumatic, and Electro-hydraulic devices: Basic elements of Pneumatics/Hydraulics and Electro-pneumatic/-hydraulic systems, construction and working of pneumatic/hydraulic cylinders and actuators, their mounting and operations, Pneumatic and hydraulic valves for flow, pressure control, direction control valves, Solenoid valves, Gates, Feedback systems; Pneumatic and hydraulic element symbols.

Circuit design of pneumatic/hydraulic, electro-pneumatic systems for various sequence of operations. Control circuits for various applications like clamping, releasing, counting, stopping, safety and similar operations.
Flexible manufacturing systems: Automatic transfer, feeding, orientation devices. Various automatic transfer machines, Automated transfer lines with and without buffer storage, Automatic storage and retrieval systems, Group technology.

Learning Outcomes:

By the end of this course, undergraduate students should be able to:

- explain the working of various pneumatic and hydraulic components,
- select the suitable devices for designing pneumatic and hydraulic systems required for automated operations,
- design the pneumatic/hydraulic circuits and understand the working of such system,
- understand the automation in manufacturing and assembly operations.

Assessment Method

- Quiz, Assignments, Mid and End semester examinations

Texts and References

Text Books:

[1] Groover, M. P., Automation, Production System & Computer Integrated Manufacturing, Pearson Education Asia (2004).
[2] Majumdar, S. R., Pneumatic Systems, McGraw Hill (2005).

Reference Books:

[1] Nakra, B. C., Automatic Control, New Age International (2005).
[2] Morriss, S. B., Automataed Manufacturing Systems, McGraw Hill (2006).

Sl. No.	Subject Code	Department Electives - II	L	T	P	C
1.	ME4104	Vehicle Dynamics	3	0	0	3
2.	ME4105	Mathematical Modelling of Computer Aided Design	3	0	0	3

3.	ME4106	Energy Engineering	3	0	0	3

Course Name	Vehicle Dynamics
Course Number	ME4104
L-T-P-C	3-0-0-3
Pre-requisites	Engineering Mechanics/Dynamics or equivalent course
Learning Mode	Class room lecture

Course objectives

Complies with PLOs 1 and 4

By the end of this course, undergraduate students should be able to:

- Understand rigid body dynamics analysis of wheeled vehicle system.
- Develop models for handling and stability of vehicle.

Course Content

1. Introduction to vehicle dynamics: Vehicle coordinate systems; loads on axles of a parked car and an accelerating car. Acceleration performance: Power-limited acceleration, traction-limited acceleration.
2. Tire models: Tire construction and terminology and mechanics of force generation;
3. Aerodynamic effects on a vehicle: Mechanics of airflow around the vehicle
4. Braking performance: Equations for braking for a vehicle with constant deceleration and deceleration with wind-resistance
5. Steering systems and cornering: Geometry of steering linkage, steering geometry error; steering system models
6. Suspension and ride: Suspension types—solid axle suspensions, independent suspensions; suspension geometry; roll center analysis; active suspension systems;
7. Vehicle rider excitation and comfort;
8. Roll-over: Quasi-static roll-over of rigid vehicle and suspended vehicle; transient roll-over, yaw-roll model, tripping, use of standards for design.

Learning Outcomes:

- Mathematical modeling of the vehicle dynamic system with integrations of various subsystems
- Understanding of the stability, rider comfort and rollover limits of the vehicle.
- Use of simulation tools for developing the analytical model

Assessment Method

- Quiz, mid and end semester examinations

Texts and References

Text Books:

1. T.D. Gillespie, “Fundamental of Vehicle Dynamics”, SAE Press (1995).
2. J.Y. Wong, “Theory of Ground Vehicles”, 4th Edition, John Wiley & Sons (2008).
3. Reza N. Jazar, “Vehicle Dynamics: Theory and Application”, 1st Edition, Springer (2008).
4. R. Rajamani, “Vehicle Dynamics and Control”, Springer (2006).
5. H. Baruh, Analytical Dynamics, McGraw-Hill, 1999.

Reference Books:

1. G. Genta, “Motor Vehicle Dynamics”, World Scientific Pub. Co. Inc. (1997).
2. H.B. Pacejka, “Tyre and Vehicle Dynamics”, SAE International and Elsevier (2005).
3. Dean Karnopp, “Vehicle Stability”, Marcel Dekker (2004).
4. U. Kiencke and L. Nielsen, “Automotive Control System”, Springer-Verlag, Berlin.
5. M. Abe and W. Manning, “Vehicle Handling Dynamics: Theory and Application”, 1st Edition, Elsevier (2009).

Course Number	**ME4105**
Course Credit	L-T-P-C: 3-0-0-3
Course Title	**Mathematical Modelling of Computer Aided Design**
Learning Mode	Classroom mode
Learning Objectives	Complies with PLOs 1, 3 and 4 By the end of this course, students will be able to: 1. Understand the mathematical concepts underlying CAD. 2. Apply mathematical techniques to model geometric entities. 3. Develop algorithms for geometric modelling. 4. Analyze and solve geometric problems using numerical methods.
Course Description	Implement mathematical models in CAD software. This course explores the mathematical foundations and algorithms used in computer-aided design (CAD). Students will learn about various mathematical techniques and their applications in creating, analyzing, and manipulating geometric models. The course covers topics such as curves, surfaces, solid modelling, transformations, and numerical methods. Prerequisite: NIL
Course Outline	Introduction to Mathematical Modelling in CAD: Overview of CAD and its applications, Importance of mathematical modelling in CAD, Introduction to geometric modelling Coordinate Systems and Transformations: Cartesian and polar coordinate systems, Homogeneous coordinates, Affine transformations (translation, scaling, rotation), Composite transformations Curves in CAD: Parametric representation of curves, Polynomial curves, Bezier curves, B-splines and NURBS Surface Modelling: Parametric representation of surfaces, Bezier surfaces, B-spline surfaces, Surface-surface intersections Solid Modelling: Solid representation schemes (CSG, B-rep), Boolean operations on solids, Boundary representation (B-rep), Euler operators Geometric Interrogation: Curve and surface fitting, Intersection algorithms, Distance and angle calculations, Surface evaluation Numerical Methods in CAD: Numerical integration and differentiation, Root-finding algorithms (Newton-Raphson method), Numerical solutions of linear systems, Optimization techniques Advanced Topics in Curve and Surface Modelling: Subdivision surfaces, Implicit surfaces, Mesh generation and processing, Curve and surface smoothing Computer Graphics in CAD: Basics of computer graphics, Rasterization and rendering, Shading and lighting models, Visualization of geometric models
Learning Outcome	This course would enable the students to understand the mathematical concepts underlying CAD to apply mathematical techniques to model geometric entities and to develop algorithms for geometric modelling
Assessment Method	Mid Semester Examination, End Semester examination, Class test & quiz, Assignment, Mini Project

Text Books:

[1] "Mathematical Elements for Computer Graphics" by David F. Rogers and J. Alan Adams
[2] "Curves and Surfaces for Computer-Aided Geometric Design" by Gerald Farin
[3] "Geometric Modeling" by Michael E. Mortenson
[4] "Numerical Methods for Engineers" by Steven C. Chapra and Raymond P. Canale

Course Number	**ME4106**
Course Credit	L-T-P-C: **3-0-0-3**
Course Title	**Energy Engineering**
Pre-requisite	Thermodynamics
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 2 and 4 The objective of this course is, • To impart the knowledge of various sources of conventional and nonconventional energy.

	• To impart the knowledge of working principle of different types of power plants and their conversion efficiency. • To develop skill in renewable and non-renewable energy technology. • To design and analyze energy systems, considering sustainability and economic factors.
Course Description	This course is designed to provide the concepts of various energy sources, energy conversion principles, power plants.
Course Outline	Conventional Energy Sources: Hydel, Steam, Gas turbine, Diesel and Nuclear Power Plant, Layout, function of different components and types, Energy and Exergy analyses of power plants. Power plant Economics. Non-conventional or Renewable energy sources: Solar energy, application of solar energy, Wind, Ocean, Geothermal, Biomass Energies, Energy Conversion Principles and types. Energy and Exergy analyses of non-conventional/renewable energy conversion units. Carbon footprint.
Learning Outcome	Following learning outcomes are expected after going through this course. • Will be able to understand various sources of conventional and nonconventional energy. • Will be able to select appropriate and efficient power plant based on the availability of energy sources. • Will be able to design and analyse various energy conversion systems considering sustainability and economic factors.
Assessment Method	Mid Semester Examination (25%), End Semester examination (35%), Class test & quiz (30%), Assignment (10%)

Suggested Readings:

1. PK Nag, Power Plant Engineering, Tata McGraw Hill, 5th Ed. 2012.
2. M.M.El. Wakil, Power Plant Techniques, McGraw Hill, New York, 1985.
3. Sukathme S.P., Solar Energy Principles of Thermal Collection and Storage, 2nd Ed., TMC New Delhi,1984.
4. John R. Lamarsh and Anthony J. Baratta, "Introduction to Nuclear Engineering", Prentice Hall, 2001.
5. Elmer E. Lewis, "Fundamentals of Nuclear Reactor Physics", Academic Press Inc., 2008.
6. Houghton E.L., Carruthers, Aerodynamics for Engineering students, Butterworth-Hinemann Ltd., 2006.

Sl. No.	Subject Code	SEMESTER VIII	L	T	P	C
1.	ME42XX	Departmental Elective – III	3	0	0	3
2.	ME42XX	Departmental Elective – IV	3	0	0	3
3.	ME42XX	Departmental Elective – V	3	0	0	3
4.	ME4299	Project – II	0	0	16	8
TOTAL			**9**	**0**	**16**	**17**
GRAND TOTAL (Semester I to VIII)			**166**			

Sl. No.	Subject Code	Department Electives - III	L	T	P	C
1.	ME4201	Finite Element Method	3	0	0	3
2.	ME4202	Refrigeration and Cryogenics	3	0	0	3
3.	ME4203	Mechanics, Processing and failure of Composite Materials	3	0	0	3

Course Name	Finite Element Method
Course Number	ME4201
L-T-P-C	3-0-0-3
Pre-requisites	Elementary calculus and matrix algebra
Learning Mode	Class room lecture

Course objectives

Complies with PLOs 1 and 4

- To provide the concepts of the finite element method and its applications to a wide range of engineering problems.

Course Content

1. **Basic Concepts**: Introduction, weak formulations, weighted residual methods, linear and bilinear Forms, variational formulations, weighted residual, collocation, subdomain, least square and Galerkin's method
2. **One Dimensional Problems**: Second-order differential equations in one dimension, Basis steps, discretization, element equations, linear and quadratic shape functions, assembly, local and global stiffness matrix and its properties, boundary conditions, penalty approach, multipoint constraints, applications to solid mechanics, heat and fluid mechanics problems, axisymmetric problems
3. **Trusses, Beams and Frames**: Plane truss, local and global coordinate systems, stress calculations, temperature effect on truss members, Euler Bernoulli beam element, Hermite cubic spline functions, frame element, solution of practical problems**.**
4. **Eigen Value and Time dependent problems**: Formulation, FEM models, semidiscrete FEM models, Time approximation schemes, Applications, problems**.**
5. **Two Dimensional Problems**: Single variables in 2-D, triangular and rectangular elements, constant strain triangle, isoparametric formulation, higher order elements, six node triangle, nine node quadrilateral, master elements, modelling considerations, numerical integration, approximations errors, convergence and accuracy computer implementation.
6. **Scalar Field Problems**: Torsion, heat transfer, heat transfer in thin fins, potential flow problems, axisymmetric problems, impositions of essential BCs
7. **Elasticity and Viscous Incompressible flows Problems**: Review of equations of elasticity, stress-strain and strain-displacement relations, plane stress and plane strain problems, velocity pressure formulation, LMM and PM model, examples

Learning Outcomes:

By the end of this course, undergraduate students should be able to:

- Develop a stiffness/conductivity vector for a given partial differential equation.
- Apply engineering FEM principles to solve and evaluate primary variables such as displacement, temperature, velocity, voltage, etc and secondary variables stress and heat.
- Analyze and design engineering problems using FEM-based methods.

Assessment Method

- Quiz, Project, mid and end semester examinations

Texts and References

Text Books and Reference Books:

1. Reddy, J.N., "An Introduction to Finite Element Methods", 3rd Ed., Tata McGraw-Hill.20005 [Text Book]
2. Zienkiewicz, O. C. "The *Finite Element Method*, 3rd Edition, Tata McGraw-Hill. **2002**
3. Cook, K.D., Malkus, D.S. and Plesha, M.E., "*Concept and Applications of Finite Element Analysis*", 3th Ed., John Wiley and Sons. **1989**
4. Rao, S.S., "The Finite Element Method in Engineering", 4th Ed., Elsevier Science. 2005
5. Reddy, J.N. and Gartling, D.K "*The Finite Element Method in Heat Transfer and Fluid Dynamics*", 2rd Ed., CRC Press. 2005

Course Number	**ME4202**
Course Credit	L-T-P-C: **3-0-0-3**
Course Title	**Refrigeration and Cryogenics**
Learning Mode	Lectures

Learning Objectives	Complies with PLOs 2 and 4 Students will be able to: • Comprehend the nomenclature of refrigerants, their physical, chemical, thermodynamic requirements and the environmental concerns, • analyse various types of refrigeration systems • design different components of vapour compression refrigeration system • understand the introductory knowledge of Cryogenic Engineering. • analyse the Liquefaction process, gas separation process, thermophysical and mechanical properties of materials at cryogenic temperature.
Course Description	This course is designed to impart the necessary knowledge of the processes and components involved in refrigeration and cryogenic systems.
Course Outline	***Refrigeration*** Refrigerants: Classification and nomenclature, desirable properties of refrigerants, common refrigerants, environmental issues-Ozone depletion and global warming Refrigeration systems: Vapour compression, vapour absorption and air refrigeration system, Thermo- electric refrigeration, Cryogenics. Capacity control techniques: Hot gas by-pass scheme, Cylinder loading scheme, suction gas throttling scheme ***Cryogenics*** **Introduction** to Cryogenics and its applications **Properties of cryogens:** T-s diagram of a cryogenic fluid, Properties of cryogenic fluids: Argon, Nitrogen, Oxygen, Neon, Hydrogen (ortho/para), Helium (He^3 and He^4), Liquid He-I and He-II (superfluid He) and its applications. **Gas Liquefaction Systems:** Basics of refrigeration/Liquefaction, Production of low temperatures, Ideal thermodynamic temperature cycle, Various liquefaction cycles. J-T expansion of real gas, adiabatic expansion, Ideal thermodynamic cycle. Linde-Hampson system. **Gas Separation, storage, transportation:** Basics of gas separation, Ideal gas separation system, Principles of gas separation. **Introduction to Cryocoolers:** Cryocoolers classification and basics, Applications, Stirling cryocooler, Comparison of GM, Stirling and Pulse tube cryocooler. Introduction to Cryogenic Insulations and Vacuum Technology.
Learning Outcome	The course training will enable students to achieve the learning objectives: • Selection of an appropriate refrigerant for a given application taking into account the physical, chemical, and thermodynamic requirements and the environmental concerns • Analysis of various refrigeration and air conditioning systems, • do thermodynamic analysis of different liquefaction plants and choose a suitable method of liquefaction • display new contemporary methods and tools to carry out thermo-physical and mechanical investigations, analysis, and processing of refrigeration and cryogenic equipment.
Assessment Method	Mid Semester Examination, End Semester examination, Assignments, Quiz, and Seminar

Text books:

1. Arora C.P., 2005. Refrigeration and Air Conditioning, Tata McGraw-Hill Publishing Company Limited, New Delhi.
2. Thomas M. Flynn, "Cryogenic Engineering", second edition, CRC press, New York (2005).

Ref. Books:

3. Dossat R.J., 2008. Principles of Refrigeration, Pearson Education (Singapore) Pte. Ltd.
4. Stoecker W., 1982. Refrigeration and Air Conditioning, Tata McGraw-Hill Publishing Company Limited, New Delhi.

5. Ameen A., 2006. Refrigeration and Air Conditioning, Prentice Hall of India Private Limited, New Delhi.
6. Randall F. Barron, "Cryogenics Systems", Second Edition, Oxford University Press, New York (1985).
7. G.M Walker. "Cryocooler- Part 1: Fundamentals" Plenum Press, New York (1983).
8. G.M Walker. "Cryocooler- Part 2" Plenum Press, New York (1983).
9. Mamata Mukhopadhyay, "Fundamentals of Cryogenic Engineering", PHI Learning Pvt. Ltd, New Delhi (2010).

Course Number	**ME4203**
Course Credit	L-T-P-Cr : 3-0-0-3
Course Title	**Mechanics, Processing and failure of Composite Materials**
Prerequisite:	Knowledge of solid mechanics or equivalent course
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 1, 3 and 4 This course aims to: (1) to understand the manufacturing processes of reinforcement fibers and matrices for composites, (2) to understand the concept of tailored design philosophy (3) Explain the behavior of constituents in the composite materials (4) Develop the student's skills in understanding the different manufacturing methods available for composite material.(5)Illuminate the knowledge and analysis skills in applying basic laws in mechanics to the composite materials.(6) use failure theories for multiaxial loading to determine the composite survivability.
Course Description	This course is designed to fulfil (1) Knowledge on classification of matrix, reinforcement and type of composite material (2) Mechanics of continuous fiber composite lamina, composite properties evaluation using micro mechanics, mechanics of laminate and hybrid laminate (3) Fabrication techniques (4) To gather knowledge on failure theories of composite laminate
Course Outline	**Module 1:** Introduction to Composites: Basic Definitions and Classification of Composites, Classification based on Matrix Material, Classification based on reinforcements, Advantages and Limitations **Module 2:** Basic constituent materials in Composites: Fibers/Reinforcement Materials, Matrix Materials, Fiber reinforced Polymer (FRP) Laminated composites, Lamina & Laminate Lay-up, Ply-orientation definition **Module 3:** Micromechanics: Rule of mixture, Properties of matrix and reinforcement material, Micro mechanics relationship, Determination of strength, stiffness, Mechanics of load-transfer, Prediction of elastic constants, environmental effect and hygro-thermal effect **Module 4:** Mechanics of Laminae: Behaviour of a Laminae , Stress-Strain relations for Anisotropic and Orthotropic cases, indicial notation and tensorial representations in Elasticity, Plane Stress (Isotropic and Orthotropic cases) Transformation relations **Module 5:** Mechanics of Laminated Composites: Kirchhoff's Plate Theory, Classical Laminated Plate Theory, Stress-resultants, forces and moments, bending, buckling and vibration, environmental effect and hygro-thermal effect, Laminate Stiffness and ABD Matrices, Special Classification, Symmetric-Anti-symmetric- Non-symmetric laminates. **Module 6:** Strength and Failure theories: Maximum stress theory, Maximum Strain Theory , Tsai-Hill Theory , Tsai-Wu Theory, Comparison of Failure Theories **Module 7:** Manufacturing Processes: Hand Lay-up, Autoclave curing, Differential scanning calorimeter (DSC), Wet Lay-up and Spray-up, Vacuum bagging, Pressure bagging, Filament winding, Pultrusion, Resin Transfer Molding (RTM), Compression molding, Recycling of Composites, Hybrid Composite
Learning Outcome	Upon completion of this course the student will be able to: 1. Explain the mechanical behavior of layered composites compared to isotropic materials. 2. Apply constitutive equations of composite materials and understand mechanical behavior at micro and macro levels. Identify and explain the fundamental properties of composite materials; Determine stresses and strains relation in composites materials. 3. Identify and explain laminate conventions and stacking sequence 4. Identify and explain the fundamentals of the classical lamination theory (CLT); 5. Identify and explain the main manufacturing processes of composite products

	6. Identify failure mode of composite material and hence take appropriate approach to design and fabricate composite for practical application
Assessment Method	Mid Semester Examination (30%), End Semester examination (50%), Class test & quiz (15%), Assignment (5%)

Texts Books

1. M.W. Hyer, Stress Analysis of Fiber Reinforced Composite Materials, DEStech Publications Inc, Update Edition 2008.
2. R.M. Jones, Mechanics of Composite Materials, 2nd edition, CRC Press, 2015
3. J N Reddy and A V Krishna Moorty, Composite Structures: Testing, Analysis and Design, Springer-Verlag Berlin and Heidelberg GmbH & Co. K, 1993
4. F.L. Matthews, G.A.O. Davies, D. Hitchings and C. Scouts, Finite Element Modeling of Composite Materials and Structures, Woodhead Publishing, 2000.

Reference Books:

1. Kaw, Mechanics of Composite Materials, 2nd edition, CRC Press, 2006
2. M. Mukhopadhyay, Mechanics of Composite Materials and Structures, Universities Press, 2005
3. Gay and S. Hoa, Composite Materials: Design and Applications, 2nd edition, CRC Press, 2007
4. I.M. Daniel and O.Ishai, Engineering Mechanics of Composite Materials, 2nd edition, Oxford University Press, USA, 2005.
5. B.D. Agarwal and L.J. Broutman, Analysis and Performance of Fiber Composites, John Wiley and Sons, 2006.
6. R.F. Gibson, Principles of Composite Material Mechanics, 3rd edition, CRC Press, 2011.

Sl. No.	Subject Code	Department Electives - IV	L	T	P	C
1.	ME4204	Mechanical Characterization of Materials	3	0	0	3
2.	ME4205	Internal Combustion Engines	3	0	0	3
3.	ME4206	Micro-manufacturing	3	0	0	3

Course Name	Mechanical Characterization of Materials
Course Number	**ME4204**
L-T-P-C	3-0-0-3
Pre-requisites	Solid Mechanics
Learning Mode	Class room lecture

Course objectives

Complies with PLOs 1, 3 and 4

- Impart a thorough understanding of the mechanical behaviour of materials under various conditions.
- Teach students how to interpret the results of mechanical tests.
- Apply this knowledge to solve real-world engineering problems.

Course Content

1. Introduction

Fundamentals of elastic and plastic deformation, Role of dislocations, twinning, and slip in plastic deformation, Strengthening mechanisms in alloys, Influence of temperature, strain rate, and environment on plastic deformation, Application of mechanical properties in engineering design

2. Monotonic Tests

Tensile, compression, shear, and torsion tests, Bend test and notch tensile test, Macro, micro, and nano hardness tests, Wear testing, Hydrogen embrittlement evaluation

3. Fatigue

Low cycle fatigue, high cycle fatigue, and giga cycle fatigue, Concept of endurance limit, Basquin and Coffin-Manson laws, strain energy density laws for life prediction, Cyclic stress-strain curve analysis, Cyclic hardening/softening, Notch fatigue, Thermo-mechanical fatigue, , Rolling contact fatigue, Effect of hydrogen embrittlement on fatigue, Influence of defects on fatigue

4. Fracture

Stress concentration factor and stress intensity factor, Griffith theory, Basics of linear elastic and elastoplastic fracture mechanics, Impact toughness and ductile to brittle transition, Fracture toughness and concepts of K_{1c} and J_{1c}, Fatigue Crack Growth Rate (FCGR), and Paris law, Short crack growth and concept of K_{th}

5. Creep

Creep and creep crack growth, Stress relaxation tests, Creep-fatigue interaction,

6. Sheet Metal Forming

Concept of planar anisotropy, Forming limit diagram, Hole expansion ratio, Spring back, r-ratio and deep drawing ratio.

Learning Outcomes:

By the end of this course, undergraduate students should be able to:

- Demonstrate a comprehensive understanding of various advanced mechanical properties.
- Interpret various mechanical tests
- Apply knowledge of advanced mechanical properties to solve real-world engineering problems and enhance material performance.

Assessment Method

- Quiz, mid and end-semester examinations

Texts and References

Text Books:

1. George E. Dieter, Mechanical Metallurgy, McGraw Hill Education, 3rd Edition, 1 July 2017.
2. S. Suresh, Fatigue of Materials, Cambridge University Press, 2nd edition, June 2012.
3. T.L. Anderson, Fracture Mechanics: Fundamentals and Applications, CRC Press, 4TH EDN, 2017
4. M.N. Shetty, Dislocation and mechanical behaviour of materials, PHI, 2013.

Reference Books:

1. Prashant Kumar, Elements of Fracture Mechanics, McGraw Hill Education, 2017.
2. J. Schijve, Fatigue of Structures and Materials, Springer, 2nd ed. 2009.
3. Bruno C. De Cooman and Kip O. Findley, Introduction to the Mechanical Behavior of Steel, Association for Iron & Steel Technology, 30 Nov 2017.

Course Name	Internal Combustion Engines
Course Number	**ME4205**
L-T-P-C	3-0-0-3
Pre-requisites	Basic and Applied Thermodynamics
Learning Mode	Class room lecturer

Course objectives

Complies with PLOs 2 and 4

- To understand the fundamental Principles of IC engines.
- To explore recent advancements in combustion technologies
- To analyze the impact of alternative fuels on engine performance and emissions
- To investigate strategies for improving engine efficiency and reducing environmental impact.
- To understand the generation of undesirable exhaust emissions
- To understand the Optical diagnostics in I C Engines
- To examine the integration of hybrid and electrification technologies with I C engines

Course Content

1. **Introduction:**

   Basic Introduction to SI and CI engine, Engine Performance Parameters.

2. **Conventional fuels & Alternative fuels:**

   Energy Scenario, Transport Fuel, Petroleum Based Liquid Fuel and Their Characteristics, Straight vegetable oils, Biodiesels, Emulsified Fuels, Methanol, Ethanol, and higher versions of alcohols. Gaseous fuels include CNG, LPG, LNG, DME, hydrogen, and ammonia.

3. **Combustion in SI and CI Engines:**

   Combustion in SI engines, Flame Propagation, Stages of Combustion in SI engines, Combustion in CI engine, Stages of CI engine combustion. Knocking in SI and CI engine, Comparison of knocking in SI & CI engine, Factors Affecting Detonations. Stoichiometric Combustion of Fuels, Adiabatic Flame Temperature.

   Combustion chambers in SI and CI engines, Important Factors Considered in Combustion Chamber Design, Modern developments in IC Engines such as EGR, MPFI, GDI, HCCI and Turbocharging.

4. **Engine Ignition cooling and Lubrication system**

   Different Ignition Systems and Working, Components of battery Ignition System, parameters affecting Engine Heat Transfer, Engine Friction and Types, Factors affecting Mechanical Friction, Lubrication and its mechanism, Different Lubrication System

5. **Fuel Injection System**

   Electronic Fuel in Injection (EFI) System, Components of an EFI system, Fuel Injectors, Types of Injection, Electronic control of engines, Requirement of Diesel Injection System, Types of Injection system for CI engine, Fuel Pump, Nozzles. Importance of ECU.

6. **Measurement and Testing of Engine Performance Parameters:**

   Measurement of Speed, Fuel Consumption Measurement, Volumetric type flowmeters, Measurement of Air consumption, Types of the dynamometer, Measurement of Brake Power, Frictional Power, and Indicated Power, Endurance test of I C Engine as per Indian standard

7. **Air Pollution and its Control**

Exhaust Emissions, Effect of Various Parameter on Exhaust Emissions, Exhaust Emissions from SI and CI Engines. Exhaust gas measurement techniques (NDIR, FID, Chemiluminescence, Smoke opacimeter), Principle and working of emission reduction technologies. Indian emission standards for SI and CI engines. Comparison between US, European and Bharat stage emission standards

8. Optical Diagnostics in IC Engines:

Spray and combustion measurements in the optical engine and constant volume combustion chamber, Application of optical techniques such as High-speed imaging, Schlieren imaging, PIV, PLIF, Diffused back Illumination (DBI), Phase Doppler Anemometry (PDA), Combustion Luminosity Imaging, etc.

9. Hybrid and Electric vehicles

History of electric vehicles, Vehicle Power Plant and Transmission Characteristics, Basic architecture of Hybrid Drive trains, Power flow in HEVs. Electric and Hybrid Electric Drivetrains, Energy Storage Requirements in Hybrid and Electric Vehicles, Battery Thermal Management System.

Learning Outcomes:

By the end of this course, mechanical engineering undergraduate students should be able to:

- Students should deeply understand advanced concepts in Internal Combustion Engines.
- Understand the application of alternative fuels in I.C. Engine and their implications for future engine design and operation.
- Students should be able to identify and explain the function of various engine components and systems, such as fuel injection systems, ignition systems, and exhaust after-treatment systems.
- Understand the advanced techniques for reducing emissions from I.C. engines.
- Understand the concepts of optical diagnostic techniques in I.C. Engine and use them in real-life experiments.
- Understand the technologies of hybrid and electric vehicles.

Assessment Method

- Quiz, Seminar, mid and semester examinations

Texts and References

Text Books:

1. IC Engine Fundamentals: John B. Heywood, 2nd Edition, Mc Graw Hill, 2018
2. Fundamentals of IC Engines: P. W. Gill and James Smith, Fourth Revised Edition, Oxford IBH, 1959
3. Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design Lino Guzzella and Antonio Sciarretta, , CRC Press, 2nd Edition, 2009
4. Electric Vehicle Technology Explained: James Larminie and John Lowry, Wiley, 1st Edition, 2003

Reference Books:

5. Introduction to Internal Combustion Engines: Richard Stone, SAE Inc., 1999
6. IC Engines Combustion and Emissions, B. P. Pundir, Narosa Publications, 2010
7. IC Engine Fundamentals: V. Ganesan, Tata Mc Graw Hill
8. The Internal combustion Engine in theory and practice: C F Taylor,2nd Edition, MIT Press, Cambridge, 1985.
9. Hydrogen Fuel for Surface Transportation: Joseph Norbeck, SAE Publications, 1996.

Course Name	Micro-manufacturing
Course Number	**ME4206**
L-T-P-C	3-0-0-3
Pre-requisites	Nil
Learning Mode	Class room lecturer

Course objectives

Complies with PLOs 3 and 4

- To acquire knowledge about the need and fundamental principle of micro-manufacturing.
- To gain knowledge of various micro-machining techniques that uses conventional and non-conventional material removal approached.
- To be familiar with micro-fabrication techniques.
- To understand the metrology aspects of micro-manufactured components.

Course Content

Introduction to micro-manufacturing: definition, need/importance, applications. Size effect.
Classification of micro-manufacturing processes. Micro-machining processes: Micro-milling Tools and micro-milling technique, Micro-drilling and Macro-drilling Technique, diamond micro-machining and grinding, ultrasonic micro- machining, micro-EDM, laser beam micro-machining, micro-ECM, electron beam micro- machining, focused ion-beam techniques, abrasive micro-finishing techniques.
Micro-fabrication using deposition techniques such as epitaxial, sputtering, chemical vapor deposition (CVD) techniques and Lithography (LIGA) based techniques.
Sensors and actuators for micro-manufacturing. Metrology for micro- manufacturing.

Learning Outcomes:

By the end of this course, undergraduate students should be able to:

- Realize the importance and suitability of micro-manufacturing techniques.
- select the suitable micro-manufacturing process based on the need and requirements of the components,
- analyse and decide the viable micro-machining or micro-fabrication technique for specific requirements,
- assess the quality of the fabricated micro-scale products.

Assessment Method

- Quiz, Assignments, Mid and End semester examinations

Texts and References

Text Books:

[3] V. K. Jain, Introduction to Micromachining, Narosa Publishing House, 2010.

Reference Books:

[3] M.J. Madou, Fundamentals of Microfabrication, 2nd Edn, CRC Press, 2009.
[4] M. Adithan, Micromanufacturing: Materials, Processes, and Technology, Atlantic Publishers, 2019.

Sl. No.	Subject Code	Department Electives - V	L	T	P	C
1.	ME4207	Energy Methods and Variational Principles in Applied Mechanics	3	0	0	3
2.	ME4208	Failure Analysis of Engineering Materials	3	0	0	3
3.	ME4209	Hydraulic Machines	3	0	0	3

Course Name	Energy Methods and Variational Principles in Applied Mechanics
Course Number	**ME4207**
L-T-P-C	3-0-0-3
Pre-requisites	Mechanics of Solids
Semester	Spring
Learning Mode	Lectures

Intended Audience

BTech Final Year (Mechanical Engineering)

Course Description

- This course leverages fundamental theorems from variational calculus and solid mechanics to derive equations of mechanics using energy and variational principles. It covers the formulation and solution of initial, boundary, and eigenvalue problems through direct variational methods.

Course Objectives

Complies with PLOs 1 and 4

- Formulating the governing equations using variational principles for static bodies such as: bars, beams and plates.
- Solving problems in applied mechanics using the principle of minimum total potential energy, principle of minimum total complementary potential energy, principle of virtual work, and principle of complementary virtual work.
- Formulating and solving initial, boundary and eigen-value problems using Rayleigh-Ritz or Galerkin method.
- Applying Hamilton's principle and Lagrange equations to obtain equations of motion.

Course Content

1. **Introduction and Mathematical Preliminaries**
   Introduction to role of energy methods; historical perspective; introduction to tensor; tensor operation; properties of tensors; invariants, eigenvalues and eigenvectors of second order tensors; tensor fields; differentiation of tensors; Divergence and Stokes theorem; displacement field; deformation gradient; small strain tensor; Cauchy stress tensor, state of stress; conservation of linear and angular momentum; constitutive relation for linear elastic solids.
2. **Introduction to Variational Calculus**
   Variational operator; concept of a functional; extremum principles; functionals of one independent variable; functional of two independent variables; Euler equations.
3. **Fundamentals of Energy Methods**
   Concepts of work and energy; strain energy; virtual work principles; principle of total potential energy and complementary potential energy; Betti's and Maxwell's reciprocity theorems.
4. **Energy Methods for the Static Analysis**
   Analysis of longitudinal bars; Euler-Bernoulli beams and plates under static loading conditions using variational principles; separation of natural and essential boundary conditions; introduction to Ritz and Galerkin methods.
5. **Energy Methods for the Dynamics Analysis**

Hamiltonian principle for particles, rigid bodies and continuum of least action; Euler-Lagrange equation; dynamics of deformable bodies: longitudinal vibration of rod, transverse vibration of strings and Euler-Bernoulli beams.

Learning Outcomes:

- Able to understand various concepts of energy and variational principles.
- Able to derive governing equations for mechanical systems.
- Able to understand other relevant courses easily.

Assessment Method

Mid semester examination, End semester examination, Class test/Quiz, Assignments

Reference Books

Textbook:

1. Reddy, J.N., Energy Principles and Variational Methods in Applied Mechanics, 3rd Ed., John Wiley and Sons, Inc., 2017.

Suggested Books:

1. Berdichevsky, V.L., Variational Principles of Continuum Mechanics-I: Fundamentals, 1st Ed., Springer, 2009.
2. Berdichevsky, V.L., Variational Principles of Continuum Mechanics-II: Applications, 1st Ed., Springer, 2009.
3. Shames, I.H., and Dym, C.L., Energy and Finite Element Methods in Structural Mechanics, 1st Ed. New Age International Publishers, 1991

Course Name	Failure Analysis of Engineering Materials
Course Number	**ME4208**
L-T-P-C	3-0-0-3
Pre-requisites	Nil
Learning Mode	Lectures

Course objectives

Complies with PLOs 1, 3 and 4

- Provide a foundational understanding of the fundamental causes of material failure.
- Introduce students to general procedures and methodologies for conducting failure analysis.

Course Content

1. Key Sources of Failure

Design deficiencies, Material and processing faults, Improper service conditions, Residual stresses

2. Tools for Failure Analysis

Fault tree diagram, Failure mode and effects analysis (FMEA), Weibull distribution, Pareto diagram

3. Common Practices in Failure Analysis:

Defining objectives for analysis, Collecting background data relevant to the failure, Selecting and handling samples appropriately, Cleaning and preserving fractured surfaces for examination, Identifying failure modes through thorough analysis, Applying systematic approaches to failure investigation, Determining root causes of failure with precision, Following standardised reporting practices

4. Examination of Fractured Components:

Conducting initial examination of fractured surfaces, Using appropriate equipment for preliminary analysis, Preserving records of failure for detailed investigation

5. Identification of failure modes:

Classifying failure modes, Identifying specific characteristics of each mode, Distinguishing between different types of fractures, Analysing factors influencing fracture modes and defects

6. Analysis of Failure Causes:

Physical observation, Chemical analysis, Optical microscopic examination, Utilisation of scanning electron microscope (SEM) and X-ray diffraction

7. Applying Fracture Mechanics in Failure Analysis:

Fracture toughness KIc, JIC, and CTOD , Impact toughness and ductile to brittle transition
Fatigue crack growth rate behaviour, Remaining life assessment

8. Case Studies:

Failure analysis of different components, such as rail, spring, shaft, automobile chassis and wheel, pressure vessels and pipelines.

Learning Outcomes:

By the end of this course, undergraduate students should be able to:

- Understand the fundamental causes of material failure.
- Apply tools for systematic failure analysis.
- Perform detailed examination and classification of failure modes.
- Analyse failure and apply findings to real-world case studies.

Assessment Method

- Quiz, mid and end-semester examinations

Texts and References

Text Books:

1. A. K. Das, Metallurgy of Failure Analysis, Special Indian Edition, 1997, Tata McGraw- Hill.

2. Richard W. Hertzberg, Deformation and Fracture Mechanics of Engineering Materials, John Wiley & Sons Inc, 5th Edition, 2012.

Reference Books:

3. Robert H. and Bhadeshia H. H.K.D.H., Steels: Microstructure and Properties, 3rd Edition, 1995, Butterworth-Heinemann.
4. W. T. Becker, and R. J. Shipley, Metals Handbook, Failure Analysis and Prevention, Volume 11, 2002, ASM International.
5. Metals Handbook, Fractography, Volume 12,1992, ASM International.
6. Prashant Kumar, Elements of Fracture Mechanics, McGraw Hill Education, 2017.
7. George E. Dieter, Mechanical Metallurgy, McGraw Hill Education, 3rd Edition, 1 July 2017.
8. S. Suresh, Fatigue of Materials, Cambridge University Press, 2nd edition, June 2012.
9. J. Schijve, Fatigue of Structures and Materials, Springer, 2nd ed. 2009.

Course Name	Hydraulic Machines
Course Number	**ME4209**
L-T-P-C	3- 0- 0- 3
Pre-requisites	Nil
Learning Mode	Lectures

Course objectives

Complies with PLOs 2 and 4

- To gain fundamental principles behind the working of various hydraulic machines
- To analyse the problems involving hydraulic turbines and pumps
- To understand the performance characteristics of different hydraulic machines

Course Content

1. **Introduction**
   Classification of hydraulic machines- turbines and pumps, heads and efficiencies, the impact of jet on stationary and moving flat and curved vanes, the fundamental equation of hydraulic machines
2. **Hydraulic turbines**
   Classification of turbines-impulse and reaction
   Impulse turbine: Pelton turbine-components, governing mechanism, velocity triangles,
   Reaction turbine-Francis, Kaplan/Propeller-components, draft tube, governing mechanism, velocity triangles
   Performance characteristics: Main characteristics, operating characteristics, and Muschel characteristics
3. **Hydraulic pumps**
   Classification of pumps-rotodynamic and positive displacement pumps
   Rotodynamic pumps: centrifugal pumps-components, velocity triangles, cavitation, net positive suction head (NPSH), role of dimensional analysis and similitude, heads, and efficiencies, performance characteristics-main and operating characteristics
   Positive displacement pumps: reciprocating pump- components, air vessels, slip, effect of piston acceleration and effect of friction.
4. **Miscellaneous fluid machines:**
   Hydraulic crane, hydraulic ram, fluid coupling, torque converter, etc.

Learning Outcomes:

By the end of this course, undergraduate students should be able to:

- demonstrate a comprehensive understanding of various hydraulic machines
- analyse the velocity triangles to evaluate the output and efficiency of hydraulic machines
- analyse the performance characteristics of turbines and pumps
- understand the working of miscellaneous fluid machines such as cranes, rams, torque converters

Assessment Method

- Assignments, quizzes, seminar, mid-semester and end-semester examinations

Texts and References

Text Books:

1. Jagdish Lal, Hydraulic Machines Including Fluidics, Metropolitan Book Co. Ltd, 2016.
2. Terry Wright and Phillip Gerhart, Fluid Machinery Application, Selection, and Design, Second Edition, CRC Press, 2010.

Reference Books:

1. S. Pati, Fluid Mechanics and Hydraulic Machines, McGraw Hill, 2012.

2. K Subramanya, Fluid Mechanics and Hydraulic Machines-Problems and Solution, 2nd Edition, McGraw Hill, 2018.

Interdisciplinary Elective (IDE) Courses for B. Tech. (Available to students other than Dept. of ME)

Sl. No.	Subject Code	Subject Name	L	T	P	C
1.	ME2205	Manufacturing Processes for Metallic Materials	3	0	0	3
2.	ME3106	Automotive Technology	3	0	0	3
3.	ME4103	Nonlinear Dynamics and Chaos	3	0	0	3

Course Name	Manufacturing Processes for Metallic Materials
Course Number	ME2205
L-T-P-C	3-0-0-3
Pre-requisites	Nil
Learning Mode	Class room lecture

Course objectives

- To gain fundamental principles of manufacturing processes
- To understand the various approaches of manufacturing processes namely machining, casting, forming, welding, powder metallurgy for metallic materials.
- To understand the different key process parameters involved in such processes and their role.

Course Content

1. **Machining:**
   Fundamental of material removal processes, single-point cutting operations, cutting tool and tool materials, force and power consumption, tool life, basics of multi-point cutting like drilling, milling etc.
2. **Casting:**
   Sand casting processes, various elements and requisites of sand casting processes, defects in casting, concept of permanent casting processes.
3. **Forming:**
   Hot and cold forming operations, Fundamentals of forging, rolling, drawing, extrusion, basics of different sheet metal forming operations, their relative advantages and disadvantages, applications.
4. **Welding:**
   Arc welding – fundamentals, power source characteristics, Gas welding, Resistance welding, Soldering, Brazing. Welding defects.
5. **Other manufacturing processes for metallic materials:**
   Introduction to Powder metallurgy, introduction to additive manufacturing.
6. **Process suitability and applications:**
   Relative comparison about process capability, product quality, application of various manufacturing processes.

Learning Outcomes:

By the end of this course, undergraduate students should be able to:

- demonstrate a comprehensive understanding of various manufacturing processes.
- apply engineering principles to suitably select the manufacturing process for a desired application.
- identify and explain the influence of various controlling process parameters and adopt the viable approach to fabricate the products.
- understand the technologies advanced needed to enhance the process applicability.

Assessment Method

- Quiz, mid and end semester examinations

Texts and References

Text Books:

1. S. Kalpakjian and S. R. Schmid, Manufacturing Processes for Engineering Materials, Prentice Hall, 2003.
2. A. Ghosh and A. K. Mallik, Manufacturing Science, Wiley Eastern, 2010
3. M. P. Groover, Introduction to Manufacturing Processes, Wiley, 2011

Reference Books:

1. P. N. Rao, Manufacturing Technology – Vol I: Foundry, Forming and Welding, Tata McGraw Hill, 2017.
2. P. N. Rao, Manufacturing Technology – Vol II: Metal Cutting and Machine Tools, Tata McGraw Hill, 2018.
3. Introduction to Manufacturing Processes, J.A. Schey, 3nd edition. McGraw Hill, 2000

Course Name	Automotive Technology
Course Number	ME3106
L-T-P-C	3-0-0-3
Pre-requisites	Nil
Learning Mode	Class room lecturer

Course objectives

- To gain fundamental knowledge of automobile
- To explore recent advancements in automotive technologies
- To understand the components of automobile systems such as chassis, engine, transmission, brakes, clutches, electrical systems, steering system, wheel and tyre etc.
- To understand the testing, maintenance and fault diagnosis in engine, power transmission devices etc.
- To study the hybrid and electric vehicle technologies

Course Content

1. **Introduction:**
   Automobile classification and specification, Automobile chassis: General layout, types of layout and its arrangement, Body construction type and materials, Functional requirements of vehicle body, Body trim and fittings.
2. **Power Transmission systems:**
   Engines: I.C. Engine Construction and Components. Engine Cooling and Lubrication System, Fuel Supply System for petrol and diesel Engine, alternative fuels, Ignition System, Engine Testing, Engine Emissions
   Clutch: Constructional features and working of single plate, multi plate, semi centrifugal and centrifugal clutch, Calculation of surface area and number of driving and driven plates. Transmission gear box: sliding mesh, constant mesh, synchromesh gearboxes and four wheel drive.
   Propeller shaft and Final drive: Propeller shaft, universal joints, Hotchkiss & Torque tube Drives, front drive shaft types and their construction and working, Differential gearbox, rear axle. Automatic Transmission and CVT, Fault and diagnosis of the power transmission system.
3. **Axle, Suspension and Steering System:**
   Axle: Classification, types of front axle, Construction, Components and their functions, types of rear axle and application.
   Suspension: Principle, Types of suspension systems, Functional requirements of suspension systems, types and Constructional features of Front Suspension and Rear suspension system, Spring types, Rubber and Air suspensions, Factors affecting design and selection; Analysis of Suspension system: Mobility, kinematic/graphical analysis, Roll centre analysis and force analysis.
   Steering System: Steering Layout, types of steering gears, steering linkages, steering mechanism, definitions, and significance of camber, caster king, pin inclination, toe in and toe out on turn. Measurement and adjustment of various steering system layouts, steering ratio, under steering and over steering, power-assisted steering, steering geometry, wheel alignment, and diagnosis of fault.
4. **Brake system:** Components and configurations, Fundamentals of braking: braking distance, braking efficiency, weight transfer, wheel skidding, Brake proportioning and adhesion utilization, Hydraulic brake system, Power assisted brakes, ABS and EBD: Working principles, Features and advantages, Fault and diagnosis

5. **Wheel and Tyres:** Types of wheels, types of tyres, tyre construction, constituents of tyre, tyre tread pattern, tyre pressure and wear, tyre properties, tyre size, tyre maintenance.
6. **Electrical, Electronics and Safety systems:** Engine control Unit, Monitoring and Instrumentation, Safety interlocks and alarms, Lamps, Lighting and other circuits, fuel gauge, temperature gauge, wiper, speedometer and odometer. Active and Passive Safety systems.
7. **Hybrid and Electric vehicles:**
   Layout and components of electric vehicles, Vehicle Power Plant and Transmission Characteristics, Basic architecture of Hybrid Drive trains, Power flow in HEVs.

Learning Outcomes:

By the end of this course, undergraduate students should be able to:

- Demonstrate a comprehensive understanding of automotive systems such as engines, transmission, suspension, braking, and electrical systems.
- Apply engineering principles to design automotive components and systems, considering factors such as performance, efficiency, safety, and manufacturability
- Students should be able to identify and explain the function of various engine components and systems, such as fuel injection, ignition, and exhaust after-treatment systems.
- Analyze and solve engineering problems related to vehicle design, performance, and maintenance.
- Understand the technologies of hybrid and electric vehicles.

Assessment Method

- Quiz, mid and end semester examinations

Texts and References

Text Books:

1. Automotive Mechanics by William H. Crouse, Donald L. Anglin, Tata Mc Graw Hill Publication
2. IC Engine Fundamentals: John B. Heywood, 2nd Edition, Mc Graw Hill, 2018
3. Fundamentals of IC Engines: P. W. Gill and James Smith, Fourth Revised Edition, Oxford IBH, 1959
4. Automotive Vehicle Technology by Heinz Heisler, Butterworth-Heinemann Ltd; 2nd edition (17 July 2002)
5. The Automotive Chassis by Jornsen Reimpell, Helmut Stoll, Jurgen W. Betzler, SAE International, 2nd edition (2001).

Reference Books:

1. Automobile Engineering Vol- I & II by Dr. Kirpal Singh, Standard Pub.& Dist.
2. Automobile Technology by Dr. N.K.Giri, Khanna Publisher
3. Automobile Engineering by G.B.S.Narang, Khanna Publisher

Course Number	**ME4103**
Course Credit	L-T-P-C: **3-0-0-3**
Course Title	**Nonlinear Dynamics and Chaos**
Pre-requisite	NIL
Learning Mode	Lectures
Learning Objectives	The objective of this course is,

	• To impart the ability of solving different nonlinear systems through analytical approach • To impart the ability of solving different nonlinear systems through numerical approach as well • To impart the ability of analyzing nonlinear systems through fixed points, phase portrait, linear and nonlinear stability approaches. • To impart the ability of analyzing chaotic systems by identifying Lyapunov exponent, Poincare Map, Fractal dimension, Information dimension and other appropriate dimensions • To impart the ability of identifying Chaos, Hyper Chaos and Nonlinearity in systems and to impart the ability to deal with them across the discipline of science and engineering.
Course Description	This course is designed to fulfil the requirement of systems per se considering the inevitable nonlinearity in the system, which is usually ignored in analyzing system dynamics. Chaos and Hyper Chaos are frequently observed in systems and in general unattended.
Course Outline	**Introduction:** Linear vs. nonlinear behavior, Example across a broad spectrum of Science and Engineering. **First-order continuous time nonlinear systems:** **Autonomous systems:** Equilibrium points, linear systems, invariant sets, linearization, phase diagrams and velocity fields, behavior dependence on parameters, bifurcations of equilibria (saddle-node, pitchfork and transcritical), implicit function theorem. **Non-autonomous systems**. **Second and higher order continuous time nonlinear Systems:** conservative/non-conservative systems: Phase plane analysis, equilibrium points, linearization, stability, periodic orbits and saddle points, potential function and phase portrait, parameter-dependent conservative systems, local bifurcations, examples of global bifurcations, effect of dissipative forces. Perturbation method, Poincare-Lindstedt method, Harmonic balance and Fourier series for periodic solutions. Averaging methods, Multiple time-scale techniques, Continuation Method. **Discrete time Dynamical Systems**: One dimensional map, Cobweb plot, bifurcation diagram, two dimensional map, bifurcation diagram, Poincare map, Chaos, Lyapunov exponent, strange attractors **Delay in continuous and discrete time dynamical Systems:** Stability and Bifurcation analysis. Chaos in piecewise linear time delay system, Synchronization of Chaos. Feedback. **Hamiltonian Chaos:** Perturbed Hamiltonian system and separatrix chaos, Chirikov Standard Map, KAM theory **Chaos Control**- PID control, Nonlinear Control

	Fractals- Fractal Dimensions, Cantor Set, Julia set, Mandelbrot set, Hausdroff dimension, Information dimension, Kaplan-Yorke dimension. *Analysis of experimentally obtained data*. **Experimental Class Room Demonstration:** For class room demonstration magnetic pendulum is developed by the instructor. A few others will be developed by students as per their interest and to be demonstrated.
Learning Outcome	Following learning outcomes are expected after going through this course. • Will be able to solve nonlinear system of equations both analytically and numerically. • Will be able to apply the method of multiple scale, perturbation method, harmonic balance for solving a set of nonlinear differential equations. • Will be able obtain the interpretation of nonlinear system behavior over the linear system behavior. • Will be able to identify the Chaos in engineering system and will be able to quantify through various measures. • Will be able to derive and analyze nonlinear system behavior.
Assessment Method	Mid Semester Examination (25%), End Semester examination (35%), Class test & quiz (30%), Assignment (10%)

Suggested Readings:

1. Jordan, D. W. and Smith, P.: Nonlinear Ordinary Differential equations, 4th Edition, Clarendon Press, Oxford, 2007 ed.
2. Nayfeh, A. H and Balachandran, B.: Applied Nonlinear Dynamics: Analytical, Computational and Experimental Methods, Wiley, 2008 ed.
3. Strogatz, S. H. : Nonlinear Dynamics And Chaos: With Applications To Physics, Biology,Chemistry, And Engineering, Westview Press, 2001 ed.
4. Moon, F. C.: Chaotic Vibrations- An introduction for Applied Scientist and Engineers, Wiley-VCH, 2004 ed.
7. Sprott, J. C.: Chaos and Time Series Analysis, Oxford University Press, 2003 ed