B. Tech. – M. Tech. Dual Degree Programme from the Department of Mechanical Engineering

B. Tech. in Mechanical Engineering and M. Tech. in Mechatronics

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 Education2017 ; 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	B.Tech. Elective - I	3	0	0	3
2.	ME41XX	B.Tech. 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.	MH4199	Mechatronics Project-I	0	0	12	6
7.	MH5101	Fundamentals of Mechatronics	3	0	0	3
8.	EC5105	Embedded System	3	0	2	4
TOTAL			**18**	**0**	**26**	**28**

B. Tech. Elective - I						
Sl. No.	**Subject Code**	**Subject**	**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.	ME4104	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	**ME4104**
L-T-P-C	3-0-0-3
Pre-requisites	Nill
Learning Mode	Class room lecturer

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).

B. Tech. Elective - II						
Sl. No.	**Subject Code**	**Subject**	**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.

Course Number	**MH4199**
Course Credit	**0-0-12-6**
Course Title	**Mechatronics Project - I**

Course Learning Objective:

Complies with PLOs 1-5

- This course provides students with an opportunity to apply their theoretical knowledge and practical skills in Mechatronics to a real-world engineering project.
- Working in teams of maximum two, students will conceptualize, design, implement, and demonstrate a mechatronic system or device.
- Emphasis will be placed on interdisciplinary collaboration, project management, problem-solving, and communication skills.

Course Learning Outcome:

- Apply principles of Mechatronics to identify and define a project problem or opportunity.
- Design and develop a mechatronic system or device to meet specified requirements.
- Implement and integrate mechanical, electrical, and software components to build the project prototype.
- Test, troubleshoot, and refine the project prototype through iterative design iterations.
- Demonstrate the functionality and performance of the project prototype through a formal presentation and documentation.
- Work effectively in a team environment, demonstrating communication, collaboration, and leadership skills.
- Reflect on the project experience and identify lessons learned for future engineering endeavors.

Contents:

Introduction to Mini-Project Course and Project Selection; Overview of course objectives, expectations, and deliverables; Project proposal submission and approval process; Team formation and roles assignment; Project Planning and Management; Project scope definition and requirements analysis; Project planning, scheduling, and resource allocation; Risk assessment and mitigation strategies; Conceptual Design and System Specification; Brainstorming and idea generation techniques; System architecture design and component selection; Functional decomposition and system specification development; Detailed Design and Component Integration; Detailed mechanical design and CAD modeling; Electrical circuit design and component layout; Software development and programming for control and interface; Prototype Fabrication and Assembly; Fabrication of mechanical components using machining, 3D printing, etc.; Assembly of electrical and electronic components; Integration of software modules and system calibration Testing, Validation, and Iterative Improvement; Functional testing and validation of individual subsystems; Integration testing and system verification; Iterative design refinement based on test results and feedback; Project Documentation and Presentation; Preparation of project documentation, including

design reports, technical drawings, and user manuals; Development of a formal project presentation; Final project demonstration and evaluation

Course Number	**MH5101**
Course Credit	L-T-P-Cr: 3-0-0-3
Course Title	**Fundamentals of Mechatronics**
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 1-5 This course concerns the synergistic application of mechanics, electronics, controls, and computer engineering in the development of electromechanical products and systems through an integrated design approach. A mechatronic system will require a multidisciplinary approach for its modelling, design, development, and implementation. In the traditional development of an electromechanical system, the mechanical components and electrical components are designed or selected separately and then integrated, possibly with other components and hardware and software. In contrast, in the mechatronic approach, the entire electromechanical system is treated concurrently in an integrated manner by a multidisciplinary team of engineers and other professionals. Naturally, a system formed by interconnecting a set of independently designed and manufactured components will have a lower level of performance than that of a mechatronic system, which employs an integrated approach for design, development, and implementation. Through this course fundamentals behind the mechatronics approach shall be detailed and discussed.
Course Description	This course is designed to fulfil the introductory assessment of different electronics devices as well as different mechanical drives related to Mechatronics applications. Prerequisite: NIL
Course Outline	Module I**:** Introduction: Definition of Mechatronics, Mechatronics in manufacturing, Products, and design. Comparison between Traditional and Mechatronics approach Module II: Review of fundamentals of electronics. Data conversion devices, sensors, microsensors, transducers, signal processing devices, relays, contactors and timers. Microprocessors, Microcontrollers and PLCs. Module III: Review of fundamentals of mechanical components: Drives: stepper motors, servo drives. Ball screws, linear motion bearings, cams, systems controlled by camshafts, electronic cams, indexing mechanisms, tool magazines, transfer systems Module IV: Modelling of simple mechanical and electric systems; Building up transfer functions of dynamic systems; Block diagram analysis; Introduction to open and closed loop systems; Dynamic responses of first order and second order systems; Input signals, system stability and dynamic errors; PID Controller design and system improvement.
Learning Outcome	After attending this course, the following outcome can be expected

	➢ Comparison between Traditional and Mechatronics approach shall be found. ➢ Different electronics devices e.g., data conversion devices, sensors, microsensors, transducers, signal processing devices, relays, contactors and timers. Microprocessors controllers and PLCs shall be detailed. ➢ Different mechanical drives: stepper motors, servo drives. Ball screws, linear motion bearings, cams, systems controlled by camshafts, electronic cams, indexing mechanisms, tool magazines, transfer systems shall be discussed. ➢ PID controllers. CNC machines and part programming. Industrial Robotics shall be introduced.
Assessment Method	Mid Semester Examination (20%), End Semester Examination (40%), Class Test (10%) & Quiz (10%), Assignment (20%).

Suggested Readings:

Text Books:

1. HMT Ltd. Mechatronics, Tata Mcgraw-Hill, New Delhi, 1988.
2. G.W. Kurtz, J.K. Schueller, P.W. Claar II, Machine design for mobile and industrial applications, SAE, 1994.
3. T.O. Boucher, Computer automation in manufacturing - an Introduction, Chappman and Hall, 1996.
4. R. Iserman, Mechatronic Systems: Fundamentals, Springer, 1st Edition, 2005
5. Musa Jouaneh, Fundamentals of Mechatronics, 1st Edition, Cengage Learning, 2012
6. Clarence W. de Silva, MECHATRONICS A Foundation Course, CRC Press, Taylor & Francis Group, 2010.

Sl. No.	Subject Code	SEMESTER VIII	L	T	P	C
1.	RM6201	Research Methodology	3	1	0	4
2.	MH5201	Sensors and Actuators	3	0	0	3
3.	MH5202	Modeling and Simulation of Mechatronics Systems	3	0	0	3
4.	XX62PQ	M. Tech. Elective – I	3	0	0	3
5.	MH4299	Project-II	0	0	12	6
		TOTAL	**12**	**1**	**12**	**19**

Course Number	**MH5201**
Course Credit	L-T-P-Cr: (3-0-0-3)
Course Title	**Sensors and Actuators**
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 1 - 5 Understanding the working and design of sensors and actuators. To provide knowledge on integrating different order and multiphysics dynamic systems for accurate measurement and actuation
Course Description	Understanding of the working and design of measurement systems-classification, characteristics and calibration of different sensors. Modelling and analysis of electromechanical, Hydraulic, pneumatic, Piezoelectric and SMA actuators
Course Outline	Brief overview of measurement systems, classification, characteristics and calibration of different sensors. Measurement of displacement, position, motion, force, torque, strain gauge, pressure flow, temperature sensor sensors, smart sensor. Optical encoder, tactile and proximity, ultrasonic transducers, opto-electrical sensor, gyroscope. Principles and structures of modern micro sensors, micro-fabrication technologies: bulk micromachining, surface micromachining, LIGA, assembly and packaging Pneumatic and hydraulic systems: actuators, definition, example, types, selection. Pneumatic actuator. Electro-pneumatic actuator. Hydraulic actuator, control valves, valve sizing valve selection. Electrical actuating systems: solid-state switches, solenoids, voice coil; electric motors; DC motors, AC motors, single phase motor; 3-phase motor; induction motor; synchronous motor; stepper motors. Piezoelectric actuator: characterization, operation, and fabrication; shape memory alloys
Learning Outcome	Understanding the dynamics of sensors and actuators so as to integrate with system for measurement /actuation. Learning Systems Dynamics and being able to predict the rang of operations of multi-physics sensors and actuators
Assessment Method	Assignments, Quiz, Viva and Examination –Midterm and End term
	Suggested Readings: 1. John G. Webster, Editor-in-chief, “Measurement, Instrumentation, and Sensors Handbook”, CRC Press (1999). 2. Jacob Fraden, “Handbook of modern Sensors”, AIP Press, Woodbury (1997). 3. Nadim Maluf, “An Introduction to Microelectromechanical Systems Engineering”, Artech House Publishers, Boston (2000). 4. Marc Madou, “Fundamentals of Microfabrication”, CRC Press, Boca Raton (1997). 5. Gregory Kovacs, “Micromachined Transducers Sourcebook”, McGraw-Hill, New York (1998). 6. E. O. Deobelin and D. Manik, “Measurement Systems – Application and Design”, Tata McGraw-Hill (2004).

	7. D. Patranabis, “Principles of Industrial Instrumentation”, Tata McGraw-Hill, eleventh reprint (2004). 8. B. G. Liptak, “Instrument Engineers’ Handbook: Process Measurement and Analysis”, CRC (2003)

Course Number	**MH5202**
Course Credit	L-T-P-Cr: 3-0-0-3
Course Title	**Modelling and Simulation of Mechatronic Systems**
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 1-5 The objective of this course is • To impart the ability of analysing different mechatronics system in a unified way. • To impart the ability of deriving the governing equation of motion in electromechanical system • To impart the ability of solving obtained governing equation numerically • To impart the ability of analysing obtained simulation results for designing different mechatronics systems • To impart the ability designing different mechatronics system through frequency domain analysis
Course Description	This course is designed to fulfil the requirement of unified modelling approach in mechatronics system where systems are of multi energy domain. Besides the simulation technique will also be addressed in this course. Prerequisite: NIL
Course Outline	**Physical Modelling:** Mechanical and electrical systems, physical laws, continuity equations, compatibility equations, system engineering concept, system modelling with structured analysis, modelling paradigms for mechatronic system, block diagrams, mathematical models, systems of differential-algebraic equations, response analysis of electrical systems, thermal systems, fluid systems, mechanical rotational system, electrical-mechanical coupling. **Simulation Techniques:** Solution of model equations and their interpretation, zeroth, first and second order system, solution of 2nd order electro-mechanical equation by finite element method, transfer function and frequency response, non-parametric methods, transient, correlation, frequency, Fourier and spectra analysis, design of identification experiments, choice of model structure, scaling, numeric methods, validation, methods of lumped element simulation, modelling of sensors and actuators, hardware in the loop simulation (HIL), rapid controller prototyping, coupling of simulation tools, simulation of systems in software (MATLAB, LabVIEW) environment. **Modelling and Simulation of Practical Problems:** • Pure mechanical models • Models for electromagnetic actuators including the electrical drivers • Models for DC-engines with different closed loop controllers using operational amplifiers • Models for transistor amplifiers Models for vehicle system

Learning Outcome	Following learning outcomes are expected after going through this course. a. Will be able to derive system equation of mechatronics system through Lagrange's equation, Hamilton's equation, Hamilton's principle and Bond Graph approaches. b. Will be able to apply the notion of Galilean Causality c. Will be able obtain the state space equations for several mechatronics systems like Electrical machines including transformer, multibody dynamics including vehicle dynamics and Euler's angle, hydraulics, sensors and actuators, d. Will be able to solve state space equations numerically through Runge-Kutta Method in Matlab or in Python languages. e. Will be able to derive and analyse deformable body dynamics including modes, nodes in different coordinate systems like generalized coordinates, modal coordinates and normalized coordinates. f. Will be able to derive the linear system's response for any arbitrary excitation g. Will be able to design different mechatronics systems like seismic instruments through frequency domain analysis
Assessment Method	Mid Semester Examination, End Semester examination, Class test & quiz, Assignment, Weightage of different components of assessment will be as per the Senate.

Suggested Readings:

Text Books:

1. L. Ljung, T. Glad, "Modeling of Dynamical Systems", Prentice Hall Inc. (1994).
2. D.C. Karnopp, D.L. Margolis and R.C. Rosenberg, "System Dynamics: A Unified Approach", 2nd Edition, Wiley-Interscience (1990).
3. G. Gordon, "System Simulation", 2nd Edition, PHI Learning (2009).
4. V. Giurgiutiu and S. E. Lyshevski, "Micromechatronics, Modeling, Analysis, and Design with MATLAB", 2nd Edition, CRC Press (2009).

M. Tech. Elective - I						
Sl. No.	**Subject Code**	**Subject**	**L**	**T**	**P**	**C**
1.	ME6208	Robot Motion Planning	3	0	0	3
2.	ME6209	Non-linear Systems Dynamics	3	0	0	3
3.	ME6215	Computer Numerical Controlled Machine Tools	3	0	0	3

Course Number	**ME6208**
Course Credit	L-T-P-Cr : 3-0-0-3
Course Title	**Robot Motion Planning**
Pre-requisite	Mobile Robotics
Learning Mode	Classroom Lecture
Learning Objectives	Complies with PLOs 1, 2 and 4 • This course covers the prominent motion planning algorithms used in the area of mobile robotics. • The course will cover various motion planning algorithms and analyses.
Course Description	This course introduces students to motion planning algorithm theory and implementation which is a crucial enabling technology for imparting higher degree of autonomy to robots. Prerequisite: ME51XX/ME52XX Mobile Robotics
Course Outline	**Configuration space and topology:** Homeomorphism and diffeomorphism, differential manifolds, connectedness and compactness, parameterization of SO(3) **Potential functions:** Additive attractive/repulsive potential, distance computation using Brushfire algorithm, local minima problem, wave-front planner, navigation potential functions, sphere-space and star-space, potential function in non-Euclidean spaces **Roadmaps:** Visibility maps, Generalized Voronoi Diagram, Retract-like Structures, Canny's Roadmap algorithm, opportunistic path planner **Cell decomposition:** Trapezoidal decomposition, Morse cell decompositions, Visibility-based decompositions for Pursuit/Evasion; **Sampling-based algorithms:** Probabilistic roadmaps, Expansive spaces trees, Rapidly-Exploring Random Trees, Analysis of PRM.
Learning Outcome	After completing this course, the students will be able to implement and analyse robot motion planning algorithms.
Assessment Method	Mid Semester Examination, End Semester examination, Class test and quiz, Programming Assignments

Suggested Readings:

Text Book:

[1] H. Choset, K. M. Lynch, S. Hutchinson, G. Kantor, W. Burgard, L. E. Kavraki and S. Thrun, Principles of Robot Motion: Theory, Algorithms, and Implementations, MIT Press, Boston, 2005.

Reference Book:

[1] S. M. LaValle, "Planning Algorithms", Cambridge University Press, 2006. (Available online http://planning.cs.uiuc.edu/)

Course Number	**ME6209**
Course Credit	L-T-P-Cr : 3-0-0-3
Course Title	**Nonlinear Systems Dynamics**
Learning Mode	Classroom Lecture
Learning Objectives	Complies with PLOs 1, 2 and 4 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 analysing nonlinear system design by identifying subharmonic and superharmonic resonance, Poincare map, Liapnouv exponent. • To impart the ability of identifying Chaos and Factals in engineering systems.
Course Description	This course is designed to fulfil the requirement of designing engineering systems considering the nonlinearity in the system, which is usually ignored in system design. Prerequisite: Dynamics/Engineering Mechanics
Course Outline	**Introduction to Nonlinear Dynamical System**: Linear vs. nonlinear behavior, Classification of nonlinear Systems, Examples of structural, fluid-mechanical and chemical/biological systems, Existence and uniqueness of solutions. **First-order 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. Nonautonomous systems. **Second-order nonlinear conservative/nonconservative 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. **First-order system in the plane**: General phase plane analysis, linearization, general solution for linear systems, classification of equilibrium points, limit cycles, Bendixon's criterion and Poincare Bendixon theorem. Point mapping techniques, exact transformations, and Poincare mappings. **One-dimensional linear and nonlinear mappings**: Fixed points, linearization, stability, parameter- dependent mappings, bifurcations. **Perturbation and other approximate methods**: Introduction to regular and singular perturbation expansions through algebraic and transcendental equations; roots of equations and dependence on parameters. Perturbation method for free oscillations, secular terms,

	frequency dependence on response, Poincare-Lindstedt technique for periodic solutions, Harmonic balance and Fourier series for periodic solutions. Averaging methods, amplitude and frequency estimates, slowly varying amplitude and phase ideas, self-excited oscillations. Multiple time-scale techniques. Forced oscillations, concept of a resonance, oscillations far from resonance, near resonances and strong and weak excitations, response near primary resonance, softening and hardening nonlinearities, Duffing's equation and primary and secondary resonances, forced response of self excited systems near resonance, frequency locking and entrainment. General linear systems with constant and periodic coefficients: Concepts of stability (Lyapunov, Poincare, etc.), stability by linearization, boundedness of solutions, Mathieu's equation, transition curves and periodic solutions for Mathieu-Duffing system. **Relaxation oscillations**: The van der Pol oscillator. **Multi degree of freedom systems**: Examples, various types of resonances – external, internal, and combination, etc., response prediction using methods of averaging and multiple scales. Some more on bifurcations, structural stability and chaos. **Experimental Demonstration**: String ballooning motion. Fun with Cantilever beam of large deformation and other developed models. Electronic Circuit building. Numerical computation with Matlab/ Mathematica.
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 analyse nonlinear system behavior.
Assessment Method	Mid Semester Examination (30%), End Semester examination (50%), Class test & quiz (10%), Assignment (10%)

Suggested Readings:
Text Books:

1. Jordan, D. W. and Smith, P.: Nonlinear Ordinary Differential Equations, 3rdEdition,Clarendon Press, Oxford, 1999 ed.
2. Nayfeh, A. H. and Mook, D. T.: Nonlinear Oscillations, Wiley Interscience, NewYork., 1979ed.
3. Nayfeh, A. H and Balachandran, B. : Applied Nonlinear Dynamics: Analytical,Computational and Experimental Methods, Wiley, 2008 ed.

4. Strogatz, S. H. : Nonlinear Dynamics And Chaos: With Applications To Physics,Biology,Chemistry, And Engineering, Westview Press, 2001 ed.
5. Ogorzalek Maciej J.:Chaos and Complexity in Nonlinear Electronic Circuits, WorldScientificSeries on Nonlinear Science Series A, 1997 ed.

Course Number	**ME6215**
Course Credit	L-T-P-Cr : 3-0-0-3
Course Title	**Computer Numerical Controlled Machine Tools**
Learning Mode	Classroom Lecture
Learning Objectives	Complies with PLOs 1, 2 and 4 After completion of this course, the student should be able: • To recognize the importance of CNC technology over conventional methods • To learn the fundamentals of CNC machine tools control systems with the help of binary logic circuits and solved numerical • To learn the fundamentals of various electrical and mechanical components of CNC machines with the help solved numerical • To learn about different work and tool holding devices for CNC machines • To write CNC part programming for CNC lathe and milling with the help of solved problems • To learn the fundamentals of writing CNC program for free form surfaces after acquiring knowledge on the mathematical modeling of few contour surfaces with solved numerical • To learn designing of a CNC machine, testing and maintenance
Course Description	This course is designed to introduce the fundamentals of CNC Machine tools to get them accustomed with the control systems used, mechanical and electrical components, work and job holding devices, CNC part programming and design and maintenance of CNC machine tools Prerequisite: NIL
Course Outline	Unit I: An overview of CNC Historical perspective, Introduction to NC/CNC/DNC and its role in FMS and CIMS, Is CNC suitable for mass production, basic elements of CNC machine tools, Machine axes designation, Advantages and disadvantages of CNC machine tools, Use of CNC technology for non-machining applications, CNC machines for industry 4.0 Unit II: Classification of CNC machine tools Point-to-point control (P-T-P), Continuous control, Open-loop control, Closed-loop control, 2 and 3 axes, and 4 and 5 axes CNC machine tools Unit III: Mechanical components of CNC machine tools Drive units of the carriages in CNC machine tools: Recirculating ball screw, Roller screw, Planetary roller screws, Recirculating roller screws Unit IV: Electrical and electronics components of CNC machine tools Power units: Working principle of stepper motors, servo motors, ac servo motors etc.; Encoders: Working principle of incremental, absolute, rotary and linear encoders; Working principle of position down counter (PDC), and decoding logic circuits, Interpolators: linear, circular etc., Digital differential analyzer (DDA) hardware-based linear and curvilinear interpolation Unit V: Tooling for CNC machine tools Tool changing arrangements: manual tool changer, automatic tool changer (ATC), tool turrets, tool magazines: chain magazine, circular magazine, and box magazine Unit VI: Work-holding for CNC machine tools

	Turning center work holding methods, Work holding for machining centers Unit VII: CNC part programming Introduction to part programming, advanced programming features and canned cycles, machining of free-form (3D) surfaces: curved surface geometries, cutter path generation for curved surfaces, CNC program generation using CAM software, Remote operation Unit VIII: Design, testing and maintenance of CNC machine tools Design of CNC machine tools for static, dynamic and thermal loads, Testing and calibration of CNC machine tools for geometric, kinematic and thermal errors, Maintenance and troubleshooting operation, Online inspection features
Learning Outcome	Complies with PLOs 1, 4 and 5 The student will be able to • Apply the knowledge of CNC technology taught in this course to develop laboratory scale CNC system • Apply the knowledge of part programming to manufacture any intricate surfaces using CNC machine tools
Assessment Method	Mid Semester Examination (25%), End Semester examination (50%), Class test & quiz (15%), Assignment and Mini Project (10%)

Suggested Readings:

References:

[1] CAD/CAM: Computer-Aided Design and Manufacturing, MP Groover, PTR Prentice-Hall, New Jersey
[2] CNC machining Technology, Graham T. Smith, Springer Verlag, London
[3] Computer Numerical Control Machines and Computer Aided Manufacturing, P Radhakrishnan, New Academic Science Limited, UK
[4] Machining and CNC Technology, Michael Fitzpatrick, McGraw Hill
[5] Computer Numerical Control of Machine Tools, G.E Thyer, NewNes, 1991
[6] CAD/CAM Theory and Practice, Ibrahim Zeid and R Sivasubramanian, Tata McGraw Hill, New Delhi, 2009.

Course Number	**MH4299**
Course Credit	**0-0-12-6**
Course Title	**Mechatronics Project-II**

Complies with PLOs 1-5.

Course Learning Objective:

- This course provides students with an opportunity to apply their theoretical knowledge and practical skills in Mechatronics to a real-world engineering project.
- Working in teams of maximum two, students will conceptualize, design, implement, and demonstrate a mechatronic system or device.
- Emphasis will be placed on interdisciplinary collaboration, project management, problem-solving, and communication skills.

Course Learning Outcome:

- Apply principles of Mechatronics to identify and define a project problem or opportunity.
- Design and develop a mechatronic system or device to meet specified requirements.
- Implement and integrate mechanical, electrical, and software components to build the project prototype.
- Test, troubleshoot, and refine the project prototype through iterative design iterations.
- Demonstrate the functionality and performance of the project prototype through a formal presentation and documentation.
- Work effectively in a team environment, demonstrating communication, collaboration, and leadership skills.
- Reflect on the project experience and identify lessons learned for future engineering endeavors.

Contents:

Introduction to Mini-Project Course and Project Selection; Overview of course objectives, expectations, and deliverables; Project proposal submission and approval process; Team formation and roles assignment; Project Planning and Management; Project scope definition and requirements analysis; Project planning, scheduling, and resource allocation; Risk assessment and mitigation strategies; Conceptual Design and System Specification; Brainstorming and idea generation techniques; System architecture design and component selection; Functional decomposition and system specification development; Detailed Design and Component Integration; Detailed mechanical design and CAD modeling; Electrical circuit design and component layout; Software development and programming for control and interface; Prototype Fabrication and Assembly; Fabrication of mechanical components using machining, 3D printing, etc.; Assembly of electrical and electronic components; Integration of software modules and system calibration Testing, Validation, and Iterative Improvement; Functional testing and validation of individual subsystems; Integration testing and system verification; Iterative design refinement based on test results and feedback; Project Documentation and Presentation; Preparation of project documentation, including design reports, technical drawings, and user manuals; Development of a formal project presentation; Final project demonstration and evaluation

Suggested Reading

1. Bolton, W. (2015). Mechatronics: Electronic control systems in mechanical and electrical engineering. Pearson Education.

   Groover, M. P., & Weiss, M. A. (2016). Mechatronics: Principles and applications. Pearson Education.

Sl. No.	Subject Code	SEMESTER IX	L	T	P	C
1.	ME51XX/ ME61XX	M. Tech. Elective - II	3	0	0	3
2.	ME51XX/ ME61XX	M. Tech. Elective - III	3	0	0	3
3.	ME51XX/ EC51XX	M. Tech. Elective - IV	3	0	0	3
4.	MH5199	Mechatronics Project-III**	0	0	16	8
	TOTAL		**9**	**0**	**16**	**17**

M. Tech. Elective – II						
Sl. No.	**Subject Code**	**Subject**	**L**	**T**	**P**	**C**
1.	ME6105	Acoustics	3	0	0	3
2.	ME6106	Mobile Robotics	3	0	0	3
3.	ME6107	Digital Manufacturing and Industry 4.0	3	0	0	3

Course Number	**ME6105**
Course Credit	L-T-P-Cr: 3-0-0-3
Course Title	**Acoustics**
Learning Mode	Classroom Lecture
Learning Objectives	Complies with PLOs 1, 2 and 4 This course aims to develop an understanding of (a) The basics of the phenomenon of Acoustics (b) Mathematical modelling of the linear phenomenon (c) Application of the models for understanding basic acoustics systems such as Resonators, Filters and Ducts etc. (d) Understanding of Environmental acoustics, Community noise, Architectural noise, Underwater acoustics etc
Course Description	To provide the concepts of acoustics and its applications in wide range of engineering problems. Prerequisite: NIL
Course Outline	Acoustics: Objective-Understanding of Vibration, Sound, Noise. Mathematical basics for Acoustics- PDE, Vectors, divergence (Greens) theorem, Stokes theorem, Signal processing. Development of Wave equation, Helmholtz equation. Acoustic wave equation- Plane waves, Acoustic -Power, Intensity & measurement. Transmission, Absorption and attenuation of sound waves in fluids, Spherical Waves, monopole, dipole, quadropole and piston radiator. Radiation and Reception of Acoustic waves. Active sound control Pipes, Cavities, Waveguides, Resonators, Filters and Ducts- Plane Waves, energy dissipation, finite amplitudes and transmission phenomena, horn radiator, mufflers, silencers Noise, signaldetection, hearings and Speech-Noise spectrum and band level, combining band levels and Tones, Detecting signal in noise, Detection threshold, Ear-Thresholds, Equal loudness level contours, Critical bandwidth, Masking Loudness level, Pitch and frequency Environmental Acoustics- weighted Sound levels, Speech interference, Criteria for Community noise, Highway noise, Aircraft noise rating, Hearing loss, Legislations for Noise control Architectural acoustics, Reverberation time, Sound Absorption materials, Direct and Reverberant Live rooms, Acoustic factors in design Transduction-transducers/transmitters- anti reciprocal, reciprocal. Loudspeakers, Microphones. Introduction to Underwater Acoustics. Use of standards for design.
Learning Outcome	Analysis of Acoustic phenomenon for modeling systems with linear acoustics Understanding and designing systems such as mufflers, resonators, filters, ducts, loudspeakers, microphones etc. Understanding the effect of Acoustics- Community noise, Automotive noise, Architectural acoustics etc
Assessment Method	Mid Semester Examination (30%), End Semester examination (50%), Class test & quiz (10%), Assignment (10%)

Suggested Readings:

Text Books:

1. Fundamental of Physical Acoustics, David T Black Stock, John Wiley & Sons, Inc, 2000
2. Noise and Vibration Control Engineering: Principles and Applications Leo L. Beranek,

JohnWiley & Sons, Inc, 2005
3. Handbook of Noise and Vibration Control edited by Malcolm J. Crocker, John Wiley & Sons,Inc., New York, 2007.

Course Number	**ME6106**
Course Credit	L-T-P-Cr : 3-0-0-3
Course Title	**Mobile Robotics**
Learning Mode	Classroom Lecture
Learning Objectives	Complies with PLOs 1, 2 and 4 • This course will present various aspects of design, fabrication, motion planning, and control of intelligent mobile robotic systems. • This course presents computational aspects and practical implementation issues and thereby leads to a well rounded training.
Course Description	This course is designed to introduce students to the concepts of Mobile Robotics. The course will provide theoretical background as well as expose the students to practical aspects of Mobile Robotics. Prerequisite: Engineering Mathematics, Linear Algebra
Course Outline	**Robot locomotion:** Types of locomotion, hopping robots, legged robots, wheeled robots, stability, manoeuvrability, controllability **Mobile robot kinematics and dynamics:** Forward and inverse kinematics, holonomic and nonholonomic constraints, kinematic models of simple car and legged robots, dynamics simulation of mobile robots **Perception:** Proprioceptive/Exteroceptive and passive/active sensors, performance measures of sensors, sensors for mobile robots like global positioning system (GPS), Doppler effect-based sensors, vision based sensors, uncertainty in sensing, filtering **Localization:** Odometric position estimation, belief representation, probabilistic mapping, Markov localization, Bayesian localization, Kalman localization, positioning beacon systems **Introduction to planning and navigation:** path planning algorithms based on A-star, probabilistic roadmaps (PRM), Markov Decision Processes (MDP), and stochastic dynamic programming (SDP).
Learning Outcome	After completing this course, the students will be able to design and fabricate a mobile robotic platform and program it to apply learned theoretical concepts in practice.
Assessment Method	Mid Semester Examination, End Semester examination, Class test & quiz, Assignment with simulation and hardware building exercises.

Suggested Readings:

Text / Reference Books:

[1] R. Siegwart, I. R. Nourbakhsh, "Introduction to Autonomous Mobile Robots", The MIT Press, 2011.

[2] Peter Corke, Robotics, Vision and Control: Fundamental Algorithms in MATLAB, Springer Tracts in Advanced Robotics, 2011.

[3] S. M. LaValle, "Planning Algorithms", Cambridge University Press, 2006. (Available online http://planning.cs.uiuc.edu/)

[4] Thrun, S., Burgard, W., and Fox, D., Probabilistic Robotics. MIT Press, Cambridge, MA, 2005.

[5] Melgar, E. R., Diez, C. C., Arduino and Kinect Projects: Design, Build, Blow Their Minds, 2012.

Course Number	**ME6107**
Course Credit	L-T-P-Cr : 3-0-0-3
Course Title	**Digital Manufacturing and Industry 4.0**
Learning Mode	Classroom Lecture
Learning Objectives	Complies with PLO 1, 2 and 4 • This course will present various aspects of digital manufacture systems and industry 4.0 with smart and connected business perspective. • This course presents data analytics for digital manufacturing and practical implementation issues for cyber physical systems and thereby leads to a well-rounded training. • This course will also give theoretical and practical knowledge on unmanned aerial vehicle or drone technology, automatic guided vehicles and collaborative robotics essential for industry 4.0
Course Description	This course is designed to discuss t various aspects of digital manufacture systems and industry 4.0 with smart and connected business perspective. The course will describe required tools for cyber physical systems development. This course will also give theoretical and practical knowledge on unmanned aerial vehicle or drone technology, automatic guided vehicles and collaborative robotics essential for industry 4.0 Prerequisite: nil
Course Outline	Digital Manufacturing: theory and industrial applications; Project planning and project management with digital tools; Digital configuration and architecture; Digital manufacturing system modelling, simulation and analysis Industry 4.0: Globalization and emerging issues, the fourth revolution, LEAN production systems, smart and connected business perspective, smart factories; Cyber Physical Systems and next generation sensors; Collaborative platform and product lifecycle management; Augmented Reality and Virtual Reality; Machine Learning and Artificial Intelligence in Manufacturing; Industrial Sensing & Actuation; Industrial Internet Systems Automation and Robotic solution under the umbrella of Industry 4.0: Applications of Unmanned Aerial Vehicles (UAVs), Autonomous Guided Vehicles (AGV); Understanding the application scenarios of UAVs and AGVs for manufacturing; Key components of UAV and AGV - Sensor & Hardware, Understanding of Navigation and Path Planning.
Learning Outcome	After completing this course, the students will be able to develop digital twins of the physical system and program it to apply learned theoretical concepts for implementation of collaborative industry 4.0 platforms in practice.
Assessment Method	Mid Semester Examination, End Semester examination, Class tests, Assignments

Suggested Readings:

Reference Books:

[1] M.P. Groover, "Automation, Production Systems and Computer Integrated manufacturing", 4th Edition, Pearson Education (2016)

[2] Hamed Fazlollahtabar, Mohammad Saidi-Mehrabad, "Autonomous Guided Vehicles: Methods and Models for Optimal Path Planning", Springer, 2015.

[3] K Kumar, D Zindani and J P Davim, "Digital Manufacturing and Assembly Systems in

Industry 4.0," CRC Press, 2019
[4] J P Davim, "Manufacturing in Digital Industries: Prospects for Industry 4.0", De Gruyter, 2020
[5] P. K. Garg, "Introduction To Unmanned Aerial Vehicles," New Age International Private Limited; First edition, 2020
[6] S.K., Pal, D. Mishra, A. Pal, S. Dutta, D. Chakravarty, S. Pal, "Digital Twin – Fundamental Concepts to Applications in Advanced Manufacturing", Springer, 2021

M. Tech. Elective - III						
Sl. No.	**Subject Code**	**Subject**	**L**	**T**	**P**	**C**
1.	ME6103	Continuum Mechanics	3	0	0	3
2.	ME6109	Vehicle Dynamics and Multi-body Systems	3	0	0	3

Course Number	**ME6103**
Course Credit	**L-T-P-C:** 3-0-0-3
Course Name	**Continuum Mechanics**
Pre-requisites	Mechanics of Solids and Mechanics of Fluids
Learning Mode	Classroom lecture

Course Objectives

Complies with PLOs 1,2 and 4

- This course targets students of solid and fluid mechanics, aiming to familiarize them with the fundamentals of continuum mechanics by enhancing their problem-solving skills for engineering problems like structural mechanics, fluid dynamics and heat transfer.

Course Content

1. **Mathematical Preliminaries**
   Introduction to Tensors: Vectors and second order tensors; Tensor operation; Properties of tensors; Invariants, Eigenvalues and eigenvectors of second order tensors; Tensor fields; Differentiation of tensors; Divergence and Stokes theorem.
2. **Kinematics of Deformation**
   Continuum hypothesis, Material (Lagrangian) and Spatial (Eulerian) descriptions of motion, Displacement field, Deformation gradient, Stretch ratios, Polar decomposition of deformation gradient, Velocity gradient, Rate of deformation, Vorticity, Length, area and volume elements in deformed configuration; Material and spatial time derivatives - velocity and acceleration, Cauchy stress tensor, state of stress, concept of first and second Piola-Kirchoff stress tensors.
3. **Fundamental Laws in Continuum Mechanics:**
   Material derivatives of Line, Surface and Volume Integrals, Conservation of mass, continuity equation, Conservation of linear and angular momentum, Conservation of energy; Continuum Thermodynamics: Basic laws of thermodynamics; Energy equation; Entropy; Clausius-Duhem inequality.
4. **Constitutive Relations and Material Models:**
   Constitutive Assumptions; Ideal Fluids; Elastic Fluids, Hyperelastic Material; Notion of Isotropy; Isothermal Elasticity - Thermodynamic Restrictions, Material Frame Indifference, Material Symmetry; Hooke's law, Stokes problem, Newtonian and Non-Newtonian fluids.

Learning Outcomes:

- The students will understand the various theoretical elements of continuum mechanics, and how these elements apply to solids and fluids.
- The students will be able to derive and apply the equations of continuum mechanics in the following areas: stress and strain analysis, deformation, work and energy, theory of elasticity, viscoelasticity, theory of plasticity, fluid mechanics, and the basis for constitutive equations.
- The students will be able to use continuum theory descriptions in their research work. Furthermore, it will also be helpful for them to understand research or scientific articles with continuum formulations.

Assessment Method

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

Reference Books

1. Mase, G. T., and Mase, G. E., Continuum Mechanics for Engineers, CRC Press, 2nd Edition, 1999.

2. Malvern, L. E., Introduction to the Mechanics of a Continuous Medium, Prentice-Hall Inc., Englewood Cliffs, New Jersey, 1969.
3. Rudnicki, J. W., Fundamentals of Continuum Mechanics, John Wiley & Sons, 2015.
4. Lai, W. M., Rubin, D., and Krempl, E., Introduction to Continuum Mechanics, Butterworth-Heinemann, 4th edition, 2015.
5. Reddy, J.N., An introduction to continuum mechanics, Cambridge University Press, 2013.
6. Jog, C.S., Foundations and applications of mechanics: Volume I: Continuum mechanics, Narosa Publishing House, 2007.

Course Number	**ME6109**
Course Credit	**3-0-0-3**
Course Title	**Vehicle Dynamics and Multi-body Systems**
Learning Mode	Lectures and Simulation tools
Learning Objectives	Complies with PLOs 1, 2 and 4 Understanding the dynamics of a wheeled vehicle, various systems- tires and the mechanics, drive trains, steering, braking and suspension systems. Developing models for handling and stability vehicle. Concepts of rigid body dynamic analysis for enabling modeling of vehicle dynamic systems Prerequisite: Engineering Mechanics/Dynamics or equivalent course
Course Description	Wheeled vehicle dynamics with tire mechanics and effect of various subsystems such as drive trains, steering, suspensions, braking. Stability and safety of the vehicle. Basic concepts of rigid body dynamics which go into the mathematical modeling of the vehicle system.
Course Outline	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. Tire models: Tire construction and terminology; mechanics of force generation; rolling resistance; tractive effort and longitudinal slip; cornering properties of tire; slip angle; camber thrust; aligning moments. Aerodynamic effects on a vehicle: Mechanics of airflow around the vehicle, pressure distribution, aerodynamic forces; pitching, rolling and yawing moments; crosswind sensitivity. Braking performance: Basic equations for braking for a vehicle with constant deceleration and deceleration with wind-resistance; braking forces: rolling resistance, aerodynamic drag, driveline drag, grade, tire-road friction; brakes, anti-lock braking system, traction control, braking efficiency. Steering systems and cornering: Geometry of steering linkage, steering geometry error; steering system models, neutral steer, under-steer, over-steer, steering ratio, effect of under-steer; steering system force and moments, low speed and high speed cornering; directional stability of the vehicle; influence of front wheel drive. Suspension and ride: Suspension types—solid axle suspensions, independent suspensions; suspension geometry; roll center analysis; active suspension systems; excitation sources for vehicle rider; vehicle response properties, suspension stiffness and damping, suspension isolation, active control, suspension non-linearity, bounce and pitch motion. Roll-over: Quasi-static roll-over of rigid vehicle and suspended vehicle; transient roll-over, yaw-roll model, tripping, use of standards for design. Multi-body systems: Review of Newtonian mechanics for rigid bodies and system of rigid bodies; coordinate transformation between two set of axes in relative motion between one another; Euler angles; angular velocity, angular acceleration, angular momentum etc. in terms of Euler angle parameters; Newton-Euler equations of motion; elementary Lagrangian mechanics: generalised coordinates and constraints; principle of virtual work; Hamilton's principle; Lagrange's equation, generalized forces. Lagrange's equation with constraints, Lagrange's multiplier.
Learning Outcome	Mathematical modeling of the vehicle dynamic system with integrations of various subsystems- Tire, drive trains, suspension, steering, brakes. Understanding of the stability and rollover limits of the vehicle.

	Use of simulation tools for developing the analytical model and also rigid body analysis tools
Assessment Method	Assignments, Quiz, Mid term and end term exams

Suggested Readings:

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. A.A. Shabana, “Dynamics of Multibody Systems”, 3rd Edition, Cambridge University Press (2005).

Reference Book

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).
6. L. Meirovitch, “Methods of Analytical Dynamics”, Courier Dover (1970).
7. H. Baruh, “Analytical Dynamics”, WCB/McGraw-Hill (1999).