M.Tech. Program from the Department of Mechanical Engineering

M. Tech. in Mechatronics

Semester wise detailed syllabus

Sl. No.	Subject Code	SEMESTER I	L	T	P	C
1.	HS5111	Technical Writing and Soft Skill	1	2	2	4
2.	MH5101	Fundamentals of Mechatronics	3	0	0	3
3.	MH5102	Mechatronics Lab – I	0	0	3	1.5
4.	ME5101	Advanced Engineering Mathematics	3	1	0	4
5.	EC5105	Embedded System	3	0	2	4
6.	XX51PQ/ XX61PQ	DE–I	3	0	0	3
7.	XX61PQ	DE–II	3	0	0	3
8.	XX61PQ	IDE	3	0	0	3
	TOTAL		**19**	**3**	**7**	**25.5**

Course Number	**MH5101**
Course Credit	L-T-P-Cr: 3-1-0-4
Course Title	**Fundamentals of Mechatronics**
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 1-3. 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.

Course Number	**MH5102**
Course Credit	**0-0-3-1.5**
Course Title	**Mechatronics Laboratory-I**

Course Learning Objective:
Complies with PLOs 1-3.

- This laboratory course will introduce students to the basic practical skills of mechatronics like analog and digital signals, microprocessor and microcontroller programming, hydraulics, pneumatics, etc.

Course Learning Outcome:

- After completing this laboratory course, the students will be able to understand the practical aspects of the concepts taught in the theory course Fundamentals of Mechatronics.
- After completing this laboratory course, the students will be equipped with practical skills for Mechatronics Lab-II course.

Prerequisite: NIL

Syllabus:

Demonstration of mechatronics hardwares; servo- position and velocity control; process control; basic programming using microprocessor/microcontroller; ADC and DAC interfacing with microcontroller/microprocessor; machine condition monitoring; development of multiple sensor fusion; image based navigation and control of robot; control of non-linear systems; machine vision inspection and image surveillance; mini-projects on mechatronic system design.

Course Number	**ME5101**
Course Credit	L-T-P-C: 3-0-0-3
Course Title	**Advanced Engineering Mathematics**
Learning Mode	Hybrid
Learning Objectives	Complies with PLOs 1-4. • This course aims to train the students with the basic and advanced mathematical tools required to solve engineering problems. • Showcase the utility of mathematics towards the analysis of real-world engineering problems.
Course Description	This course is designed to fulfil the need for basic and advanced mathematics concepts often used in real-life engineering problems. Prerequisite: NIL
Course Outline	Linear Algebra: Matrix algebra; basis, dimension and fundamental subspaces; solvability of Ax = b by direct Methods; orthogonality and QR transformation; eigenvalues and eigenvectors, similarity transformation, singular value decomposition, Fourier series, Fourier Transformation, FFT. Vector Algebra & Calculus: Basic vector algebra; curves; grad, div, curl; line, surface and volume integral, Green's theorem, Stokes's theorem, Gauss-divergence theorem. Differential Equations: ODE: homogeneous and non-homogeneous equations, Wronskian, Laplace transform, series solutions, Frobenius method, Sturm-Liouville problems; PDE: separation of variables and solution by Fourier Series and Transformations, PDE with variable coefficient. Numerical Technique: Numerical integration and differentiation; Methods for solution of Initial Value Problems, finite difference methods for ODE and PDE; iterative methods: Jacobi, Gauss-Siedel, and successive over-relaxation. Complex Number Theory: Analytic function; Cauchy's integral theorem. Statistical Methods: Descriptive statistics and data analysis, correlation and regression, probability distribution.
Learning Outcome	• This course would enable the students to solve the mathematical governing equations of engineering problems. • The students would be able to realise the connection of Mathematics with Physics and Engineering.
Assessment Method	Mid Semester Examination, End Semester examination, Class test & quiz, Assignment, Class Performance and Viva

Suggested Readings:

Text Books:

1. H. Kreyszig, "Advanced Engineering Mathematics", Wiley, (2006).
2. Gilbert Strang, "Linear Algebra and Its Applications", 4th edition, Thomson Brooks/Cole, India (2006).
3. J. W. Brown and R. V. Churchill, "Complex Variables and Applications", McGraw-Hill Companies, Inc., New York (2004).
4. J. W. Brown and R. V. Churchill, "Fourier Series and Boundary Value Problems", McGraw-Hill Companies, Inc., New York (2009).

5. G. F. Simmons, “Differential Equations with Applications and Historical Notes”, Tata McGraw-Hill Edition, India (2003).
6. S. L. Ross, “Differential Equations” 3rd edition, John Wiley & Sons, Inc., India (2004).
7. K. S. Rao, “Introduction to Partial Differential Equations”, PHI Learning Pvt. Ltd (2005).
8. R. Courant and F. John, “Introduction to Calculus and Analysis, Volume I and II”, Springer-Verlag, New York, Inc. (1989).
9. K. Atkinson and W. Han, “Elementary Numerical Analysis” 3rd edition, John Wiley & Sons, Inc., India (2004).
10. R. A. Johnson and G. K. Bhattacharya, “Statistics, Principles and Methods”, Wiley (2008).
11. Michael D Greenberg, “Advanced Engineering Mathematics”, 2nd Edition, Pearson (1998).
12. R.K. Jain and S. R. K. Iyengar, “Advanced Engineering Mathematics” 4th Edition, Narosa; 1st Edition (2002).

Department Elective - I						
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
4.	EC5114	Advanced Digital Image Processing	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 3 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 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 • 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

Department Elective - II						
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
3.	EC6104	VLSI Signal Processing	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 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 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).

Sl. No.	Subject Code	SEMESTER II	L	T	P	C
1.	MH5201	Sensors and Actuators	3	0	0	3
2.	MH5202	Modeling and Simulation of Mechatronic Systems	3	0	0	3
3.	MH5203	Mechatronics Lab – II	0	0	3	1.5
4.	XX62PQ	DE-III	3	0	0	3
5.	XX62PQ	DE-IV	3	0	0	3
6.	XX52PQ/ XX62PQ	DE-V	3	0	0	3
7.	RM6201	Research Methodology	3	1	0	4
8.	IK6201	IKS	3	0	0	3
	TOTAL		**21**	**1**	**3**	**23.5**

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 1-3. 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)

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<tr><td>Course Number</td><td>MH5202</td></tr>
<tr><td>Course Credit</td><td>L-T-P-Cr: 3-0-0-3</td></tr>
<tr><td>Course Title</td><td>Modelling and Simulation of Mechatronic Systems</td></tr>
<tr><td>Learning Mode</td><td>Lectures</td></tr>
<tr><td>Learning Objectives</td><td>Complies with PLOs 1-3.
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</td></tr>
<tr><td>Course Description</td><td>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</td></tr>
<tr><td>Course Outline</td><td>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</td></tr>
<tr><td>Learning Outcome</td><td>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</td></tr>
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	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).

Course Number	**MH5203**
Course Credit	**0-0-3-1.5**
Course Title	**Mechatronics Laboratory-II**

Course Learning Objective:
Complies with PLOs 1-3.

- This laboratory course will introduce students to the advanced practical skills of mechatronics like Sensors, Actuators, Numerical Control, Industrial Robotics, hydraulics, pneumatics, etc.
- To understand the working principles of various mechatronics components such as sensors, actuators, controller, etc.
- To provide practical experience on the functioning of various mechatronics components and systems
- To provide hands-on experience on development of different mechatronic systems

Course Learning Outcome:

- After completing this laboratory course, the students will be equipped with skills necessary for solving problems related to mechatronics encountered in industry.
- After completing this laboratory course, the students will get a practical appreciation of the theoretical courses taught in the Executive M-Tech program.
- Ability to identify different mechatronics components and their basic structure
- Ability to acquire data from different sensors in mechatronic system and control of physical system through controller
- Ability to design and fabricate a mechatronic system to solve real life problem

Prerequisite: **MH5102**

Syllabus:

NC machine tool; microprocessor/ microcontroller based control; Industrial Robotics; Smart actuators; hydraulics; pneumatics; Sensors; Actuators; PCB Design and Fabrication; mini-projects on mechatronic system design.

Department Elective - III						
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 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: ME6106 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 System Dynamics**
Learning Mode	Classroom Lecture
Learning Objectives	Complies with PLOs 1, 3 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 2 and 3 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.

Department Elective - IV						
Sl. No.	**Subject Code**	**Subject**	**L**	**T**	**P**	**C**
1.	ME6206	Microfluidics and Microsystems	3	0	0	3
2.	ME6210	Robotics: Advanced Concepts & Analysis	3	0	0	3

Course Number	**ME6206**
Course Credit	L-T-P-C: 3-0-0-3
Course Title	**Microfluidics and Microsystems**
Learning Mode	Classroom lecture
Learning Objectives	Complies with PLOs 1 and 2 • Equip the students with basics of fluid mechanics at microscale, unique phenomenon dominant at microscale and their benefits for real life. • To understand this interdisciplinary science of microfluidics which uses knowledge from fluid mechanics at microscale, chemistry, Electrostatics, Micro-electromechanical systems (MEMS) and Biology to help humanity by designing novel microsystems such as point of care diagnostic devices.
Course Description	Microfluidics is the research discipline dealing with transport phenomena and fluid-based devices at microscopic length scales of microns. This course aims to fulfil the need of basic understanding about fluid flow at microscale. Further, it introduces the students with electrostatics and its utility towards design of new microfluidic systems such as electroosmotic pump and Knudsen pump. In the later part, distinct types of microfabrication techniques are explained. The last chapter introduces many modern techniques related to biomedical engineering and medical science such as DNA sequencing, micropumps and point of care diagnostic devices. Prerequisite: NIL
Course Outline	**Introduction:** Origin, Definition, Fluid quantity, Benefits, Challenges, Commercial activities. **Scaling laws**: Scaling in nature, Scaling of physical systems, Trimmer's vertical bracket notation, limitations. **Micro-scale flows**: Intermolecular forces, States of matter, Continuum assumption, Governing equations, Constitutive relations, Gas and liquid flows, Boundary conditions, Slip theory, Transition to turbulence, Low Re flows, Entrance effects, Liquid film flow in an inclined plane, Couette flow, Poiseuille flow, Stokes drag on a sphere, Time-dependent flows, Two-phase flows, Couette flow with slip, Hydraulic resistance and Circuit analysis, Straight channel of different cross-sections, Channels in series and parallel. **Capillary flows**: Surface tension and interfacial energy, Young-Laplace equation, Contact angle, Capillary length and capillary rise, Interfacial boundary conditions, Marangoni effect. **Electrokinetics**: Electrohydrodynamics fundamentals, Electro-osmosis, Dielectrophoresis, Electro-capillary effects, Continuous electro-wetting, Direct electro-wetting, Electro-wetting on dielectric. **Microfabrication**: Materials, Clean room, Silicon crystallography, Miller indices, Oxidation, Photolithography- mask creation, spin coating, exposure and development, Etching, Bulk micromachining,

	Wafer bonding, Polymer microfabrication: PMMA/COC/PDMS substrates, micromolding, hot embossing, fluidic interconnection. **Microfluidics Components**: Micropumps, Microvalves, Microflow Sensors, Micromixers, Droplet Generators, Microparticle Separators, Microreactors, DNA sequencers, Point of Care Devices.
Learning Outcome	At the end of the course, students will have achieved the following learning objectives: • Design a microfluidic network to meet the need of a microluidic system by minimizing the overall drag reduction. • Be capable of understanding the design of existing microfluidic systems such as micropumps, Micro-reactors, DNA sequencer and other point of care devices. • To be equipped to design and develop new microfluidic systems.
Assessment Method	Mid Semester Examination, End Semester examination, Class test & quiz, Assignment, Term Paper Presentation

Suggested Readings:

Text/Reference Books:

1. Nguyen, N. T., Werely, S. T., Fundamentals and applications of Microfluidics, Artech house Inc., 2002.
2. Bruus, H., Theoretical Microfluidics, Oxford University Press Inc., 2008.
3. Madou, M. J., Fundamentals of Microfabrication, CRC press, 2002.
4. Tabeling, P., Introduction to microfluidics, Oxford University Press Inc., 2005.
5. Kirby, B.J., Micro- and Nanoscale Fluid Mechanics: Transport in Microfluidic Devices, Cambridge University Press, 2010.
6. Colin, S., Microfluidics, John Wiley & Sons, 2009.

Course Number	**ME6210**
Course Credit	L-T-P-Cr : 3-0-0-3
Course Title	**Robotics: Advanced Concepts and Analysis**
Learning Mode	Classroom Lecture
Learning Objectives	Complies with PLOs 1-3 • This course gives various aspects of kinematics, dynamics, motion planning, and control of robotic manipulators • This course presents computational aspects, control aspects and practical implementation of multi degree of freedom manipulators for industrial application
Course Description	This course is designed to fulfil the basic and advanced concepts of kinematics, dynamics, motion planning, and control of industrial Robotics. The course will provide theoretical background as well as expose the students to practical aspects of Robotic manipulators. Prerequisite: NIL
Course Outline	Introduction to robotics: brief history, types, classification and usage and the science and technology of robots. Kinematics of robot: direct and inverse kinematics problems and workspace, inverse kinematics solution for the general 6R manipulator, redundant and over-constrained manipulators. Velocity and static analysis of manipulators: Linear and angular velocity, Jacobian of manipulators, singularity, static analysis. Dynamics of manipulators: formulation of equations of motion, recursive dynamics, and generation of symbolic equations of motion by computer simulations of robots using software and commercially available packages. Planning and control: Trajectory planning, position control, force control, hybrid control Industrial and medical robotics: application in manufacturing processes, e.g. casting, welding, painting, machining, heat treatment and nuclear power stations, etc.; medical robots: image guided surgical robots, radiotherapy, cancer treatment, etc. Advanced topics in robotics: Modelling and control of flexible manipulators, wheeled mobile robots, bipeds, etc. Future of robotics.
Learning Outcome	• After completing this course, the students will be able to design and fabricate a robotic arm for some practical applications • Students will able to operate and control a robotic system using the theoretical concepts learned in this course
Assessment Method	Mid Semester Examination, End Semester examination, Class tests, Assignments, mini-projects

Suggested Readings:

Reference Books:

[1] M. P. Groover, M. Weiss, R. N. Nagel and N. G. Odrey, “Industrial Robotics-Technology, Programming and Applications”, McGraw-Hill Book and Company (1986).
[2] S. K. Saha, “Introduction to Robotics”, Tata McGraw-Hill Publishing Company Ltd. (2008).
[3] S. B. Niku, “Introduction to Robotics–Analysis Systems, Applications”, Pearson Education (2001).
[4] A. Ghosal, Robotics: “Fundamental Concepts and Analysis”, Oxford University Press (2008).

[5] Pires, "Industrial Robot Programming–Building Application for the Factories of the Future", Springer (2007).
[6] Peters, "Image Guided Interventions – Technology and Applications", Springer (2008).
[7] K. S. Fu, R. C. Gonzalez and C.S.G. Lee, "ROBOTICS: Control, Sensing, Vision and Intelligence", McGraw-Hill (1987).
[8] J. J. Craig, "Introduction to Robotics: Mechanics and Control", 2nd edition, Addison-Wesley (1989).