Department of Mechatronics
B. Tech. in Mechatronics

Year	Sub. Code	Subject Name	L	T	P	C	Sub. Code	Subject Name	L	T	P	C
	THIRD SEMESTER						**FOURTH SEMESTER**					
II	MAT ****	Engineering Mathematics – III	2	1	0	3	MAT ****	Engineering Mathematics – IV	2	1	0	3
	MTE ****	Data Structures and Algorithms	2	1	0	3	MTE ****	Theory of Machines	2	1	0	3
	MTE ****	Digital Design and Verilog Programming	2	1	0	3	MTE ****	Design of Machine Elements	3	1	0	4
	MTE ****	Digital and Analog CMOS Design	3	0	0	3	MTE ****	Industrial Automation	3	0	0	3
	MTE ****	Mechanics of Robotics Systems	2	1	0	3	MTE ****	Linear Control Theory	2	1	0	3
	MTE ****	Sensors and Transducers	3	0	0	3	MTE ****	Microcontroller based System Design	2	1	0	3
	MTE ****	Industrial Robotics Lab	0	0	3	1	MTE ****	CAD and Kinematics' Simulation Lab	0	0	3	1
	MTE ****	Integrated Electronics Lab	0	0	3	1	MTE ****	Microcontroller Lab	0	0	3	1
	MTE ****	Manufacturing Processes Lab	0	0	3	1	MTE ****	Sensors and PLC Lab	0	0	3	1
			14	**4**	**9**	**21**			**14**	**5**	**9**	**22**
	Total Contact Hours (L + T + P)		**27**				**Total Contact Hours (L + T + P)**		**28**			
	FIFTH SEMESTER						**SIXTH SEMESTER**					
III	HUM ****	Engg. Economics and Financial Management	2	1	0	3	HUM ****	Essentials of Management	2	1	0	3
	MTE ****	Digital Signal Processing	2	1	0	3	MTE ****	Energy and Heat Transfer	3	0	0	3
	MTE ****	Electric Drives	3	1	0	4	MTE ****	Automobile Engineering	3	0	0	3
	MTE ****	Manufacturing Technology	2	1	0	3	MTE ****	Program Elective – I	3	0	0	3
	MTE ****	Hydraulics and Pneumatics Systems	3	0	0	3	MTE ****	Program Elective – II	3	0	0	3
		Open Elective – I				3		Open Elective – II				3
	MTE ****	Drives, Controls and Modelling Lab	0	0	3	1	MTE ****	Hydraulics Lab	0	0	3	1
	MTE ****	Robot Operating System Lab	0	0	3	1	MTE ****	IIoT Lab	0	0	3	1
							MTE ****	Pneumatics Lab	0	0	3	1
			12	**4**	**6**	**21**			**14**	**1**	**9**	**21**
	Total Contact Hours (L + T + P) + OE		**22 + 3 = 25**				**Total Contact Hours (L + T + P) + OE**		**24 + 3 = 27**			
	SEVENTH SEMESTER						**EIGHTH SEMESTER**					
IV	MTE ****	Program Elective – III	**3**	**0**	**0**	**3**	MTE ****	Industrial Training				1
	MTE ****	Program Elective – IV	**3**	**0**	**0**	**3**	MTE ****	Project Work/Practice School				12
	MTE ****	Program Elective – V	**3**	**0**	**0**	**3**	MTE ****	Project Work (Only for B. Tech. Hons.)				20
	MTE ****	Program Elective – VI	**3**	**0**	**0**	**3**	MTE ****	BTech Honors (Theory 1)** (V Sem)				4
	MTE ****	Program Elective – VII	**3**	**0**	**0**	**3**	MTE ****	BTech Honors (Theory 2) ** (VI Sem)				4
		Open Elective – III				**3**	MTE ****	BTech Honors (Theory 3) ** (VII Sem)				4
	MTE ****	Mini Project (Minor Specialization) *										

		15	**0**	**0**	**18/26**					**13/ 33**
	Total Contact Hours (L + T + P) +OE	**15 + 3 = 18**								

Minor Specialization

I. Hybrid and Electric Vehicle Technology
MTE ****: Autotronics
MTE ****: Hybrid and Electric Vehicles
MTE ****: Vehicle Dynamics
MTE ****: Modelling of Hybrid and Electric Vehicles

II. Industrial IoT Systems
MTE ****: Database Management Systems
MTE ****: Cyber Security for Industrial Automation
MTE ****: Internetworking for Industries
MTE ****: Principles of Cryptography

III. Robotics and Automation
MTE ****: Artificial Intelligence for Robotic Vision
MTE ****: Robot Dynamics and Control
MTE ****: Robot Path Planning and Mobile Robots
MTE ****: Soft Robotics

IV. Micro and Nano Systems
MTE ****: Semiconductor and VLSI systems
MTE ****: Smart Materials for Micro and Nano Systems
MTE ****: Design of Micro and Nano Devices
MTE ****: Fabrication and Testing of Micro Systems

V. Precision Agriculture Technology
MTE ****: Smart Farming Machinery
MTE ****: Robotics and Automation in Agriculture
MTE ****: Food Process Automation
MTE ****: Digital Agriculture

VI. Computational Mathematics
MAT ****: Applied Statistics and Time Series Analysis
MAT ****: Computational Linear Algebra
MAT ****: Computational Probability and Design of Experiments
MAT ****: Graphs and Matrices

VII. Business Management
HUM ****: Financial Management
HUM ****: Human Resource Management
HUM ****: Marketing Management
HUM ****: Operations Management

Other Program Electives
MTE ****: Antennas, Radar and Navigation
MTE ****: Augmented Reality and Virtual Reality
MTE ****: Autonomous Mobile Robotics
MTE ****: Biomechatronics
MTE ****: Building Automation
MTE ****: Cloud Computing
MTE ****: Data Analytics and Machine Intelligence
MTE ****: Data Mining and Visualization
MTE ****: Digital Manufacturing
MTE ****: Deep Learning for Computer Vision
MTE ****: Design of Mechanical Drives
MTE ****: Electric Vehicles
MTE ****: Embedded Systems and RTOS
MTE ****: Engineering Materials
MTE ****: Fractional Order Modelling and Control
MTE ****: Human Robot Interaction
MTE ****: Machine Learning
MTE ****: Machine Tool Technology
MTE ****: Machine Vision
MTE ****: Mechanical Vibrations
MTE ****: Micro and Nano Fabrication of Electronic Devices
MTE ****: Micro Electro Mechanical Systems
MTE ****: Micro-manufacturing Systems
MTE ****: Nanotechnology
MTE ****: Object Oriented Programming using Python
MTE ****: Production and Operations Management
MTE ****: Reinforcement Learning for Robotics
MTE ****: Renewable Energy Technology
MTE ****: Sustainable Manufacturing
MTE ****: Systems Modelling and Simulation
MTE ****: Wireless Sensor Networks

Open Electives
MTE ****: Autonomous Mobile Robots
MTE ****: Farm Automation
MTE ****: Hydraulics and Pneumatics Systems
MTE ****: Industrial IoT
MTE ****: Introduction to Industrial Robotics

*Applicable to students who opted for minor specialization
** Applicable to eligible students opted for and successfully completed the B Tech – Honours requirements

THIRD SEMESTER

MAT ****: ENGINEERING MATHEMATICS - III [2 1 0 3]

At the end of the course the students will be able to:

CLO1	Solve the boundary vale problems (ODE) by finite difference method.
CLO2	Understand the concepts of finite difference to partial differential equations.
CLO3	Understand the concept of Fourier Series, Fourier transforms, its properties and applications.
CLO4	Understand vector differential and integral calculus, their properties and applications.
CLO5	Understand Concept of linear PDEs, One-dimension Heat and Wave equation and their solutions by different methods.

Gradient, divergence and curl,. Line, surface and volume integrals. Green's, divergence and Stoke's theorems. Fourier series of periodic functions. Half range expansions. Harmonic analysis. Fourier integrals. Sine and cosine integrals, Fourier transform, Sine and cosine transforms. Partial differential equation- Basic concepts, solutions of equations involving derivatives with respect to one variable only. solutions by indicated transformations and separation of variables. One-dimensional wave equation, one dimensional heat equation and their solutions. Numerical solutions of boundary valued problems, Laplace and Poisson equations and heat and wave equations by explicit methods

References:

1. Erwin Kreyszig: *Advanced Engineering Mathematics*, (5e) 1985 Wiley Eastern.
2. S.S.Sastry : *Introductory Methods of Numerical Analysis* (2e)1990, Prentice Hall.
3. B.S.Grewal : *Higher Engg.Mathematics*, 1989 Khanna Publishers
4. Murray R.Spiegel : *Vector Analysis*, Schaum Publishing Co.

MTE ****: DATA STRUCTURES AND ALGORITHMS [2 1 0 3]

At the end of the course the students will be able to:

CLO1	Articulate data structures along with their operations of insertion and deletion.
CLO2	Appraise the data structures and their properties for different industrial applications.
CLO3	Appraise the time complexity of algorithms and sorting techniques viz. Insertion sort, Bubble sort, Selection sort and Heap sort.
CLO4	Implement text processing algorithms on applications for pattern searching in a text.
CLO5	Distinguish between the algorithms for graph search on various real-time problems.

Introduction to Python Programming: Data types. I/o statements, Conditional and Looping statements, Functions. Stacks, Queues, Evaluation of expressions, Linked lists-singly, doubly, header node, circular along with application. Trees- Binary trees, In-order, Preorder and Post order traversal of Trees. Creation, Insertion and Deletion operations on Binary search tree. Sorting – Bubble sort, Selection sort, Merge sort, Quick sort, Heap sort. Searching – Linear search, Binary search. Horspool algorithm, Open Hash table, Floyd's algorithm, Warshall's algorithm, Prim's algorithm, Kruskal's algorithm, Dijkstra's algorithm.

Self-study:

Courseera course entitled Python programming for all

References:

1. Bradley N. Miller, David L. Raum, *Problem Solving with Algorithms and Data Structures using Python*, (3e), FBA Publishers, 2018.
2. Agarwal Basant, Baka Benhamin, *Hands-On Data Structures and Algorithms with Python*, (2e), Packt Publishing, 2018.
3. Dinesh P. Mehta, Sartaj Sahni, *Handbook of Data Structures and Applications*, (2e), CRC Press, 2018.

MTE **** DIGITAL DESIGN AND VERILOG PROGRAMMING [2 1 0 3]

At the end of the course the students will be able to:

CLO1	Design and realize combinational and sequential logic circuits using various design approaches, logic optimization techniques
CLO2	Design asynchronous and synchronous finite state machines (FSM) for given specifications.
CLO3	Develop Verilog code for combinational and sequential logic circuits using different modeling styles like gate level, data flow, behavioral and switch level.
CLO4	Compare and evaluate the digital implementation options and architecture of FPGAs.
CLO5	Analyse, understand the principles of engineering ethics, sustainability, environmental health, safety, hazards in semiconductor industries.

Logic Families, Review of logic minimization techniques, Weighted and unweighted codes, Binary Adder/ Subtractor, BCD Adder, code converters, Binary comparators, Parity generator/ checker. Combinational circuit design using logic blocks: multiplexers, demultiplexers, encoders, priority encoder, decoder; Shannon's decomposition, Sequential Logic Design: Latches, Flip-flops: Design of synchronous and asynchronous counters, Shift registers, Synchronous Sequential machines: classification, finite state machine (FSM), analysis and design, Introduction to Verilog HDL:

VHDL versus Verilog, Structural modeling, Data-flow Modeling, Behavioral Modeling, Switch Level Modeling, Tasks and Functions, Test Bench, Digital Implementation Options and FPGA Architectures: Full-custom and semi-custom, PLD, ASICs: CPLDs, MPGAs and FPGAs, Architecture of ACTEL and XILINX logic family.

Self-Study:

Shannon's decomposition, E-waste Management, Risks and Hazards involved in circuit design, Safety and Hazards in semiconductor industry, semiconductor industries for sustainable future.

Prereequisite:

K map reduction, Boolean algebraic expression minimization

References:

1. Zvi Kohavi, Niraj K Jha, *Switching and Finite Automata Theory,* (3e), Cambridge, 2010.
2. Morris Mano, *Digital design*, (3e), Prentice Hall of India, 2002.
3. Floyd and Jain, *Digital Fundamentals*, (11e), Pearson Education, 2015.
4. A. Anand Kumar, *Switching Theory and Logic Design*, (2e), Prentice Hall of India, 2009
5. Bhasker. J, A *Verilog HDL Primer*, (3e), Star Galaxy, 2016.
6. Stephen. Brown and Zvonko Vranesic, *Fundamentals of Digital Logic with Verilog Design*, (3e), Tata McGraw Hill, 2014.
7. M. J. S. Smith, *Application Specific ICs*, Pearson Education, 2004.

MTE ****: DIGITAL AND ANALOG CMOS DESIGN [3 0 0 3]

At the end of the course the students will be able to:

CLO1	Realise combinational circuits using switch logic and gate logic with CMOS style.
CLO2	Explain the CMOS fabrication process.
CLO3	Apply the properties of analog building blocks to realise circuits.
CLO4	Design linear, non-linear and active-RC filter applications of op-maps.
CLO5	Design digital-to-analog converters and analog-to-digital converters for given specifications.

Moore's law, VLSI technology trends, BJT versus MOS, MOSFET: types, VI characteristics and regions of operation, second-order effects, NMOS and CMOS inverter, pass transistors and transmission gates, CMOS circuit realisation of combinational circuits using switch logic and gate logic, CMOS fabrication process, Stick diagrams, Layouts, delay unit, CMOS inverter delay, Analog versus digital, Analog building blocks: Current Mirror, VFOA, CFOA, CCII, OTA. Operational Amplifier: block diagram representation, ideal and practical characteristics, Linear and non-linear applications of Op-amp, Active-RC filters, Data converters.

References:

1. Pucknell D. A and Eshraghian K, *Basic VLSI Design*, (3e), PHI Publication, 2015.
2. R. Jacob Baker, Harry W. Li, David E. Boyce, *CMOS: Circuit design, Layout, and Simulation* Wiley-IEEE Press, 2019.
3. Ramakant A. Gaikwad, *Op-Amps and Linear Integrated Circuits*, Prentice Hall of India, (4e), 2015.
4. Stanley William D., *Operational Amplifiers with Linear Integrated Circuits*, Prentice Hall, 2004.
5. Franco Sergio, *Design with Op-amps and Analog Integrated Circuits*, McGraw Hill, (3e), 2017.
6. Choudhury Roy D and Shail B. Jain, *Linear Integrated Circuits*, Wiley Eastern, (4e), 2018.

MTE ****: MECHANICS OF ROBOTICS SYSTEMS [2 1 0 3]

At the end of the course the students will be able to:

CLO1	Develop the fundamental understanding of various components of a robot and comprehend its role in selecting a robot.
CLO2	Apply algebraic tools for the description of frame representation and relate one frame to the other frame.
CLO3	Apply forward kinematics and inverse kinematics to compute position of end-effector and joint variables respectively.
CLO4	Construct the Jacobian and apply fundamental laws to derive the dynamic formulation.
CLO5	Utilize the methods for trajectory planning and the motion of robot in joint space.

Introduction to robotics- types and specification of robots, DoF, configurations, control resolution, spatial resolution, accuracy and repeatability, actuators and sensors, drives and transmission systems used in robotics. Kinematic analysis & coordinate transformation-Direct kinematic problem in robotics, homogeneous transformation matrices, joint space, and cartesian space, Denavit-Hartenberg method, Inverse manipulator kinematics solvability, robot kinematics constraints, robot workspace, holonomic robots, Jacobian matrix, Jacobian singularity. Trajectory generation- general considerations in path description and generation, joint-space schemes, cartesian-space schemes. Manipulator dynamics-Newton's equation, Euler's dynamic formulation, iterative vs. closed form. Lagrangian Formulation of Dynamics, Introduction to 3D rigid body dynamics: The Inertia Tensor. Kinematic modeling of planar and spatial parallel manipulators, Closed-loop equation, four-bar and slider-crank mechanism, Stewart platform. Feedback and closed-loop control (SISO & MIMO), second-order linear systems, Case studies.

Self-study:

Kinematic configurations of the industrial robot, case studies on different industrial manipulator working principles and applications or mini project.

References:

1. John J. Craig, *Introduction to Robotics: Mechanics and Control,* (3e), PHI, 2005.
2. C. Peter., *Robotics, Vision and Control: Fundamental Algorithms in MATLAB*. Vol. 73. Springer, 2011.
3. G. Ashitava, *Robotics: Fundamental Concepts and Analysis*, Oxford University Press, 2006.
4. Murray, Richard M., Zexiang Li, S. Shankar Sastry, and S. Shankara Sastry, *A Mathematical Introduction to Robotic Manipulation*, CRC press, 1994.
5. S. Bruno and O. Khatib, *EDS: Springer handbook of Robotics*, Springer, 2016.
6. Mittal, R. K., and I. J. Nagrath. Robotics and control. Tata McGraw-Hill, 2003.
7. Niku, Saeed B. Introduction to robotics: analysis, control, applications. John Wiley & Sons, 2020.

MTE **: SENSORS AND TRANSDUCERS [3 0 0 3]**

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

CLO1	Analyze the characteristics and error analysis of any electromechanical instrument and sensors.
CLO2	Determine accurately electrical quantities using analog and digital voltmeters, ammeters, DC bridges, AC bridges, LCR-Q meter, and cable fault detection methods.
CLO3	Apply appropriate sensors and transducers for measuring physical quantities with understanding the material science concepts related to the manufacturing of sensors and transducers.
CLO4	Demonstrate an understanding of signal conditioning concepts such as filters, amplifiers, attenuation, linearization, electrical isolation, surge protection, and digital storage oscilloscope.
CLO5	Apply the significance of the various standards and ethical considerations related to industrial automation along with their safety and risk mitigation.

Units and standards, calibration, static and dynamic characteristics of an instrument, error analysis, electromechanical measuring instruments. Material science concepts: materials used for manufacturing sensors and transducers. analog and digital voltmeters, ammeters, LCR-Q meters, DC bridges, AC bridges, cable fault detection, shielding and grounding, introduction to sensors and transducers. Types of sensors, Physics behind sensors, Selection and calibration of sensors. Measurement of physical quantities- position, velocity, acceleration, proximity, strain, force, temperature, pressure, flow, level, humidity, light, gas sensors, LiDAR, Radar sensors, oxygen sensors, breath analyzers, heart rate sensor. Sensor applications, transmitters, Digital Storage Oscilloscope, Data acquisition system, Signal conditioning. IEC, ISO, IP standards, Electrical safety, Engineering ethics, Case study.

Prerequisite:

Understanding of physics, solving basic electrical circuits

Self-Study:

Risk assessment and mitigation

References:

1. Sawhney A.K., *A Course in Electrical and Electronic Measurements and Instrumentation*, (28e), Dhanpat Rai & Co., 2020
2. Boyes W., *Instrumentation Reference Book*, Butterworth-Heinemann, (4e), 2009
3. Murty D.V.S., *Transducers and Instrumentation*, (2e), Prentice Hall India Learning Private Limited, 2012.
4. Charles B. Fleddermann, *Engineering ethics*, (4e), Pearson, 2012.
5. Bela G. Liptak, *Process Measurement and Analysis*, (4e), CRC press, 2003.

Online Courses:

1. Ethics, Technology and Engineering -Coursera https://www.coursera.org/learn/ethics-technology-engineering
2. Responsible Innovation: Ethics, Safety and Technology-edX https://www.edx.org/course/responsible-innovation-ethics-safety-and-technology
3. Sensor Manufacturing and Process Control (Coursera)
4. Sensors and Sensor Circuit Design (Coursera)

MTE ****: INDUSTRIAL ROBOTICS LAB [0 0 3 1]

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

CLO1	Interface specific sensors, actuators and program using Arduino
CLO2	Implement Robot vision applications with OpenCV
CLO3	Develop graphical solutions for robotics work cell and program robot manipulator using teach-pendant.
CLO4	Implement a mini project by working as a team with individual goals

Introduction to Robot Studio an offline Programming Tool, Defining Targets and Trajectory Generation, Creating a Custom Tool and Defining a Work object, Conveyor Tracking using Robot Studio. Manual programming using Teach pendant for IRB2600, Control of Digital Inputs and Outputs through IRB2600 Robot, automation applications with industrial robot IRB2600 and collaborative robot Universal Robot UR5. Control of Stepper Motor and servo motor actuators using Raspberry PI. PID Control of Lego Line Following Robot. Robot Vision- with image processing software or Open CV.

Self study topics:

Kinematic modeling of the industrial robot, knowledge of Sensors and actuators for case study or mini project.

References:

1. S. Bruno and O. Khatib, *EDS: Springer handbook of Robotics*, Springer, 2016.
2. Niku, Saeed B. Introduction to robotics: analysis, control, applications. John Wiley & Sons, 2020.
3. C. Peter., Robotics, Vision and Control: Fundamental Algorithms in MATLAB. Vol. 73, Springer, 2011.
4. Operating manual RobotStudio, ABB Robotics, 2021
5. Sherlock Machine Vision Software User's Reference Manual, for Software versions 7.1.x and 7.2.x.

MTE ****: INTEGRATED ELECTRONICS LAB [0 0 3 1]

At the end of the course the students will be able to:

CLO1	Analyze and design linear and non-linear circuits using Op-Amp IC 741, demonstrating an understanding of its functionality and limitations.
CLO2	Evaluate and synthesize timer circuits using 555 IC, including astable, monostable, and bistable configurations.
CLO3	Create and troubleshoot voltage regulator circuits using 78xx and LM317 ICs, exhibiting an understanding of their specifications and applications.
CLO4	Construct and validate combinational logic circuits using digital ICs, including logic gates, multiplexers, and demultiplexers.
CLO5	Develop and verify sequential logic circuits using digital ICs, such as flip-flops, shift registers, and counters, employing clock signals and timing analysis.

Introduction to op-amp using 741IC, linear applications of Op-amp, Operational amplifier and block diagram representation, characteristics of operational amplifier, Analyze and design linear and non-linear applications of Op-Amp using 741 IC. Design Timer circuits using 555 IC and voltage regulator using 78xx, and LM317 ICs. Design combinational and sequential logic circuits using digital ICs.

References:

1. Stanley William D., *Operational Amplifiers with Linear Integrated Circuits*, 4(e), Prentice Hall, 2004.

MTE ****: MANUFACTURING PROCESSES LAB [0 0 3 1]

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

CLO1	Practice electrical welding and fabricate different welded joints.
CLO2	Demonstrate the Foundry and Smithy Practices
CLO3	Practice lathe operations: Turning, Step Turning, Threading, Chamfering.

CLO4	Program a CNC Turning center and Machining Center for machining components
CLO5	Practice shaper, milling and grinding operations
CLO6	Apply the knowledge of industry standards, risk mitigation, human safety while designing and operating on the mechanical components for different manufacturing real-time applications

Introduction to machine shop, foundry and smithy shop. Preparation of the models by lathe involving turning, thread cutting, knurling operations, preparation of models using milling, shaping and surface grinding machines; operation of CNC milling and turning center, preparation of arc welding models. Demonstration of Wire-EDM, TIG and MIG welding process.

Self-Study:

Case studies on various manufacturing processes for designing a component

References:

1. Chaudhury S. K. Hajara & Others, *Elements of Workshop Technology Vol 1 & 2, (5e), Media* Promoters & publishers Pvt.Ltd ., Mumbai, 2004.
2. R.K. Jain, *Production Technology, (2e),* Khanna Publishers, New Delhi, 2002.
3. Raghuwanshi, B.S., *A course in Workshop technology, Vol 1 & II,* DhanpatRai & Sons, New Delhi.

FOURTH SEMESTER

MAT ****: ENGINEERING MATHEMATICS IV [2 1 0 3]

At the end of the course the students will be able to:

CLO1	Solve problems on probability, conditional probability and Chebyshey inequality.
CLO2	Solve one dimensional and two dimensional random variables and evaluate mean and variance of random variables.
CLO3	Identify the various types of distribution and find the probability of random sample space, curve fitting.
CLO4	Solving problems on difference equations and Z transforms.
CLO5	Finding the series solution of difference equations, Bessel and Legendre equations.

The z transforms, properties of z transforms, initial and final value theorems, solution of difference equations by the method of z transforms, convolution theorem. Special functions: Series solutions of ordinary differential equations ,Series solutions of Bessel’s and Legendre’s differential equations, Recurrence relations and generating functions. Orthogonal properties, Probability: Finite sample space, conditional probability and independence, Bayes’ theorem, one dimensional random variable: mean and variance, Chebyshev's inequality.Binomial, Poisson, uniform, normal, gamma, chi-square and exponential distributions. Two and higher dimensional random variables ,Covariance, correlation coefficient, regression lines, least square principles of curve fitting. Moment generating function, Functions of random variables, Sampling theory, Central limit theorem and applications

References:

1. Kreyzig E -.*Advanced Engineering Mathematics*, (7e). , Wiley Eastern.
2. Meyer P.L. - *Introduction to Probability and Statistical applications*, (2e). American Publishing Co.
3. Ross S.M. - *Introduction to Probability and Statistics for Engineers and Scientists*, (2e). Wiley International.
4. Grewal B.S - *Higher Engineering Mathematics*, Khanna Publishers.
5. Hogg & Craig - *Introduction of Mathematical Statistics*, (7e).2013. MacMillan

MTE ****: THEORY OF MACHINES [2 1 0 3]

At the end of the course the students will be able to:

CLO1	Analyse the various kinematic concepts of mechanisms, their inversions, mechanisms with lower pair and determine the degrees of freedom and mobility of various mechanisms
CLO2	Assess a mechanism for displacement, velocity, and acceleration at any point in a moving link using graphical approach.
CLO3	Analyse the unbalancing masses in the system and balance the unbalanced rotating masses under both static and dynamic conditions.
CLO4	Perform the speed, torque analysis of various gears and gear train
CLO5	Analyse the working of cam and follower for the given application

Introduction to mechanisms and machines: Kinematics and Dynamics, Mechanisms and Machines, Plane and Space Mechanisms, Mechanisms and their Inversions. Kutzbach and Grubler's criterion, Grashof's criterion. Other mechanisms: Straight line Mechanism, Toggle mechanism, Pantograph, Hooke's joint, Ackermann and Davis steering gear, Geneva mechanism and Ratchet mechanism. Analysis and synthesis of planar mechanisms: Velocity and acceleration analysis, Corioli's component of acceleration. Balancing and Dynamic force analysis: Power Smoothening by Flywheels. Gears and Gear trains. Cams and followers.

Self-study:

Mechanisms used in robotic applications and analysis of velocity and acceleration of varoius links used in industrial robots

References:

1. John J. Uicker Jr.,Gordon R. Pennock, Joseph E. Shigley, *Theory of Machines and Mechanisms*, (5e) OUP USA, 2017.
2. Rattan. S. S, *Theory of Machines*, (4e), Tata Mc Graw Hill, New Delhi, 2017.
3. Bevan. T, *Theory of Machines*, (4e), Laxmi Publications, New Delhi, 2016.
4. Ghosh and Mallick. A. K, *Theory of Machines and Mechanisms*, (3e), Affiliated East West Private Limited New Delhi, 2008.
5. Ballaney P. L, *Theory of Machines and Mechanisms*, Khanna Publishers, New Delhi, 2005.

MTE ****: DESIGN OF MACHINE ELEMENTS [3 1 0 4]

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

CLO1	Determine principal stresses and planes, bending stresses, torsional stresses and deflection in a given beam/component with knowledge of static theory of failures.
CLO2	Describe mechanical design process through design of elements subjected to static and fatigue loadings.
CLO3	Design helical springs and power screws for mechanical systems by identifying the failure modes.
CLO4	Design spur gears and rolling contact bearings for mechanical systems by identifying the failures modes.
CLO5	Determine stresses in transmission shafts subjected to bending, torsional and combined loads for a given application.

Stresses and Strains: Shear force and bending moments. Types of loads and stresses. Bending and Torsional Stresses: Types of beams and supports, theory of simple bending, stress variation in beams, analysis of torsion in shafts, shear stress in shafts and stress distribution, Deflection of Beams: Deflection of beams by double integration method and Macaulay’s method. Static and Dynamic Loading: Stress concentration, fatigue strength, stress-life (S-N) diagram, Design of Transmission Shafts: Materials, permissible stresses, permissible deflection and permissible angular twist, power transmitting elements, design for static and fatigue load (bending and torsion), ASME code for shaft design. Design of Helical Springs: Helical coil spring: Power Screws: Power Screws: Types of power screws, terminology, torque for power screws, collar friction, efficiency, Design of Spur Gears: Spur gears, terminology, tooth profile, pressure angle, Lewis equation for beam strength, form factor, velocity factor, Selection of Bearings: Definition, objective, viscosity and types of lubrication. Construction, application, merits and demerits of journal bearing. Rolling Contact Bearings: Types, capacity of bearings, bearing life, loading ratio, equivalent bearing load and bearing selection.

Self-study:

Mechanical components used in robotic applications and design of these components used in industrial robots

References:

1. Timoshenko and Young, *Elements of Strength of Materials*, Tata McGraw Hill, New Delhi, 2003.
2. Popov E.P., *Engineering Mechanics of Solids*, Prentice Hall India, New Delhi, 2001.
3. Beer F. P. and Jonhston R, *Mechanics of Materials*, (3e), MacGraw Hill Book Company, 2002
4. Shigley J. E. and Mischke C. R., *Mechanical Engineering Design*, (5e), McGraw Hill Inc, New York. 2004.
5. Bhandari V B., *Design of Machine Elements*, (2e), Tata McGraw-Hill Publishing Company Limited, Newh Delhi, 2007

MTE ****: INDUSTRIAL AUTOMATION [3 0 0 3]

At the end of the course the students will be able to:

CLO1	Explain the construction, working, and importance of industrial automation
CLO2	Familiar with industrial sensor, actuator, Drives, and motors used in manufacturing and process industries.
CLO3	Impart the role of PLC, DCS, HMI and SCADA in industry automation
CLO4	Expose to various communication protocol used industrial automation
CLO5	Know the importance and advancement of automation technology

Introduction to industrial automation, types of automation; architecture of industrial automation, Industrial revolutions, advantages and limitations of Automation, and trends in industrial automation. Sensors and actuators used in industry: Sensors, Transmitters, Actuators and Signal Conditioning: Measurements with Industrial Field Instruments, Data Acquisition Systems. Drives and motors: Types of motors and Drives. Industrial Controllers and drives: PLC, PID, DCS, Industrial monitoring: HMI and SCADA. Industrial Communication and networking: Device network: CAN, PROFIBUS-PA, HART, Control network: ControlNet, PROFIBUS-DP, Ethernet, Interfaces: RFID, Barcode. Safety instrument used in automation technology. Overview of Industrial robots. Advancement industrial automation: Industry 4.0 and Industrial IoT.

Self-study:

NPTEL, Coursers, Swayam and Edx
Case study from industry journal (Electronics for you and Automation-ISA)

References:

1. Stamatios Manesis, George Nikolakopoulos, *Introduction to Industrial Automation*, CRC Press, 2018 .
2. Chanchal Dey, Sunit Kumar Sen, *Industrial Automation Technologies*, CRC Press, 2020.

3. Frank Lamb, *Industrial Automation: Hands On*, McGraw-Hill Professional, 2013.
4. A.K. Gupta, S.K. Arora, Jean Riescher Westcot, I*ndustrial Automation and Robotics: An Introduction*, Mercury Learning & Information, 2016.
5. Zongwei Luo, Zongwei Luo, *Robotics, Automation, and Control in Industrial and Service Settings*, IGI Global; Engineering Science Reference, 2015.

MTE **: LINEAR CONTROL THEORY [2 1 0 3]**

At the end of the course the students will be able to:

CLO1	Apply the concept of mathematical modeling, block diagram reduction techniques, and Mason's Gain formula to obtain the transfer function of the linear system.
CLO2	Analyze the stability of the linear systems in the time domain for different test signals.
CLO3	Analyze the Steady State errors, frequency domain stability, and Compensator design for the linear systems.
CLO4	Analysis of a linear control system using Bode plot, composite Controllers, and State Space Representation.
CLO5	Apply the various risk and safety measures for the industrial control system.

Feedback control systems terminologies, control system design process. differential equation of physical systems, linear approximation, frequency domain representation, Time domain analysis and design, first and second order system response analysis, time domain and Steady State Error (SSE), stability, RH criteria, root locus technique. Introduction to compensator design, design of lag, lead, and lag-lead compensating network. Frequency domain analysis- frequency response, Bode plot construction and interpretation of system behaviour, gain margin & phase margin, relation between time domain & frequency domain specification, SSE characteristics from frequency response, P, PI and PID Controllers and their tuning.

Self-study:

Topics related to safety and risk measures for industrial control system from

- Dave Macdonald, Practical Industrial Safety, Risk Assessment and Shutdown Systems for Industry, 2004.
- Yasushi Nakagawa, Functional Safety in Industrial Automation, 2022.

References:

1. Norman S. Nise, *Control Systems Engineering*, (6e), Wiley India, 2010
2. R.C Dorf, R. H. Bishop, *Modern Control Systems*, (12e), PEARSON, India, 2011.
3. B.C. Kuo, F. Golnaraghi, *Automatic Control Systems*, (10e), TMH, India, 2017.
4. K. Ogata, *Modern Control Engineering*, (5e), PEARSON, India, 2010.
5. M. Gopal, *Control System: Principles and Practices*, (4e), TMH, India, 2016.

MTE **: MICROCONTROLLER BASED SYSTEM DESIGN [2 1 0 3]**

At the end of the course the students will be able to:

CLO1	Analyse the developments of microcomputers and its architecture
CLO2	Design embedded applications using assembly language instruction sets for advanced RISC microcontrollers.
CLO3	Develop an algorithm using Embedded C to solve complex engineering problems involving sensors and actuators
CLO4	Use microcontroller-based systems for case study examples addressing social, legal, ethical, and functional safety standards

Microcomputer: Significance of Microcomputer Technology, Digital Vs Analog Computing and Types of Instruction set Computing. ARM Cortex M series: Introduction to ARM Cortex A series, Cortex R series & Cortex M series. Introduction to Cortex M4: Architecture, Memory Mapping, Types of registers. Instruction sets in assembly: Data Movement, Arithmetic, Logical, Memory addressing, Bitwise, Branching, and Subroutine. Calculation of delay. Introduction to Embedded C: C programming Vs Embedded C, GPIO, System Timer, NVIC, Watchdog Timer, Clock Select, Timer-32, Timer-A, PWM Generation, UART Communication. Case studies.

References:

1. Bai, Ying. Microcontroller Engineering with MSP432: Fundamentals and Applications. Crc Press, 2016.
2. Unsalan, Cem, H. Deniz Gurhan, and M. Erkin Yucel. Programmable Microcontrollers: Applications on the MSP432 LaunchPad. McGraw Hill Professional, 2017.
3. MSP432 Manual by Texas Instrumentation.

MTE ****: CAD AND KINEMATICS' SIMULATION LAB [0 0 3 1]

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

CLO1	Analyze and draw various 2 D sketches for machine components.
CLO2	Develop 3 D models of simple machine components, assemble and draft them.
CLO3	Simulate simple mechanisms to obtain position, velocity, and acceleration parameters of different links by performing kinematic simulation.

2D sketcher exercises of simple machine components, solid modeling and assembly exercise of machine components like 6 axis robot, CPU fan, bench vice, screw jack. Kinematic analysis of simple mechanisms like slider crank mechanism, 4 bar mechanism, cam and follower mechanism.

Self-study:

Udemy course entitled Complete CATIA V5 express training.

References:

1. Gopalkrishna K. R., *Machine Drawing*, Subhas Publications, Bangalore, 2002.
2. Bhat N.D., *Machine Drawing*, Charotar Publishing House, Anand, 2002.
3. Venugopal K., *Engineering drawing and graphics + Auto CAD*, Newage International ublishers, Delhi 2002.
4. Narayana K.L. and Kannaiah P, *Text Book on Engineering drawing*, Scitech Publications, Chennai 2002.

MTE ****: MICROCONTROLLER LAB [0 0 3 1]

At the end of the course the students will be able to:

CLO1	Identify the real-world scenarios where Embedded system might be applied using the Keil package.
CLO2	Apply the concepts of assembly language instruction set for solving complex engineering problems
CLO3	Apply the basic concepts of embedded c programming for MSP432P401R microcontroller applications.
CLO4	Develop logical solution using embedded c programming for microcontroller-based application that includes GPIO, NVIC Timers, ADC, PWM etc

Introduction to Keil software, Assembly programming: Familiarization of assembly instructions, Data Movement, Arithmetic, Logical instructions, Memory addressing, Bitwise, Branching instructions, and Subroutines. Introduction to Embedded C programming, GPIO programming, hardware interfacing, delay generation using SysTick Timer, Timer-32, PWM Generation using Timer-A, serial communication using UART, ARM controller based system design.

Self-study:

Risk and safety assessment for microcontroller-based system.

References:

1. Bai, Ying. *Microcontroller Engineering with MSP432: Fundamentals and Applications*. CRC Press, 2016.
2. Unsalan, Cem, H. Deniz Gurhan, and M. Erkin Yucel. *Programmable Microcontrollers: Applications on the MSP432 LaunchPad*. McGraw Hill Professional, 2017.
3. MSP432 Manual by Texas Instrumentation.
4. https://www2.keil.com/mdk5/uvision/

MTE ****: SENSORS AND PLC LAB [0 0 3 1]

At the end of the course the students will be able to:

CLO1	Identify the industrial sensor and draw the characteristic
CLO2	Implement a wiring connection with different logical combination
CLO3	Demonstrate the hardware and software components of PLC
CLO4	Develop ladder programming for different industrial application
CLO5	Create an individualistic prototype model using sensors and PLC technology

Behavior of inductive, magnetic, reflection light scanner, and one way barriers, reflection light barrier OBS and an ultrasonic sensor. Path power characteristic curve of inductive analog encoder, reduction factor of reflection light scanner OJ, fitted with an optical waveguide. Response curve of inductive sensor, capacitive sensor, magnetic field sensors. Switching frequency and switching distance and hysteresis of NBN, CJ, MB, OJ. Calculation of maximum admissible velocity of an object using ultrasonic sensor. Introduction of PLC, study basic components, networking and different programming technique. Of PLC. Study NO, NC and holding circuit programs, Implement of Simple Ladder program, to study basic functions of timers, counters, math, logical and program control instructions. Study different applications using ladder logic.

Self-study:

Siemen and Allen Bradely manual
https://instrumentationtools.com

References:

1. *Siemens PLC manual*, Siemens.
2. *PLC training practice module*, BOSCH REXROTH manual Germany 2011.
3. John W. Webb and Ronald A. Reiss, *Programmable logic controllers-Principle and applications*, (5e), PHI, 2005.
4. *Sensorics training system practice module*, BOSCH REXROTH manual, Germany 2011.
5. *Sensors in theory and practice*, BOSCH REXROTH AG Germany 2007.

FIFTH SEMESTER

HUM ****: ENGINEERING ECONOMICS AND FINANCIAL MANAGEMENT [2 1 0 3]

At the end of the course the students will be able to:

CLO1	Compute the worth of money at various points of time.
CLO2	Apply various Depreciation methods in determining the value of an asset.
CLO3	Describe and apply basic techniques of Financial Statement.

CLO4	Evaluate the replacement of an existing asset based on standard replacement analysis techniques.
CLO5	Evaluate the best alternative in Engineering Economics problems considering risk and safety.

Time value of money, Interest factors for discrete compounding, Nominal & effective interest rates, Present and future worth of Single, Uniform, and Gradient cash flow. Related problems and case studies. Bases for comparison of alternatives, Present worth amount, Capitalized equivalent amount, Annual equivalent amount, Future worth amount, Capital recovery with return, Rate of return method, Incremental approach for economic analysis of alternatives, Replacement analysis. Break even analysis for single product and multi product firms, Break even analysis for evaluation of investment alternatives. Physical & functional depreciation, Straight line depreciation, declining and double declining balance method of depreciation, Sum-of-the-Years Digits, Sinking Fund and Service Output Methods, Case Study. Balance sheet and profit & loss statement. Meaning & Contents. Ratio analysis, financial ratios such as liquidity ratios, Leverage ratios, Turn over ratios, and profitability ratios, Drawbacks. Safety and Risk, Assessment of Risk and safety, Case study, Risk Benefit Analysis and Reducing Risk.

References:

1. Chan S. Park, "Contemporary Engineering Economics", 4th Edition, Pearson Prentice Hall, 007.
2. Thuesen G. J, “Engineering Economics”, Prentice Hall of India, New Delhi, 2005.
3. Blank Leland T. and Tarquin Anthony J., “Engineering Economy”, McGraw Hill, Delhi, 2002.
4. Prasanna Chandra, “Fundamentals of Financial Management”, Tata McGraw Hill, Delhi, 2006.
5. Mike W. Martin and Roland Schinzinger, “Ethics in Engineering”, Tata McGraw Hill, New Delhi, 2003.
6. Govindarajan M, Natarajan S, Senthil Kumar V. S, “Engineering Ethics”, Prentice Hall of India, New Delhi, 2004.

MTE ****: DIGITAL SIGNAL PROCESSING [2 1 0 3]

At the end of the course the students will be able to:

CLO1	Classify signals and systems based on their fundamental characteristics
CLO2	Analyze digital signals and systems by applying z-transform and frequency domain transformation (obtained through DFT).
CLO3	Design linear digital filters (FIR and IIR) for a given application.
CLO4	Design a system for a real time application using DSP Processor.
CLO5	Apply the knowledge of industry standards, E-waste management, ethics, risk mitigation, and electrical safety for real time application

Introduction to Signal Processing, operations on signals, Properties of signals and systems, Impulse Response and convolution, Sampling, Aliasing, Transform domain analysis of discrete-time systems: Z Transform and application of Z transforms, Discrete Fourier Transform, Fast Fourier Transform. Digital Filter Characteristics and structures, IIR Filter Design using Butterworth approximations. Bilinear transformation methods. FIR Filter Design using Window method. Applications of digital signal processing- speech, image, video, communication, acoustics and vibration.

References:

1. Oppenheim A.V, Willsky A.S, *Signals and Systems*, (2e), PHI,2011.
2. Oppenheim A.V. and R.W. Schafer, *Discrete time signal processing*, (2e), Prentice-Hall, 2001.
3. Proakis J.G. and D.G. Manolakis, *Digital Signal Processing: Principles, Algorithms and Applications*, (3e), PHI, 2007.
4. Sanjit K.Mitra, Digital Signal Processing – A computer-based approach(4e), McGrawHill Education, 2013

MTE **: ELECTRIC DRIVES [3 1 0 4]**

At the end of the course the students will be able to:

CLO1	Describe the fundamental principles, components, dynamics and control of Electric Drives.
CLO2	Classify the power electronic converters for power conversion applications by selecting suitable power semiconductor devices.
CLO3	Analyse the DC Machine drives and their control strategies using suitable power electronic topologies.
CLO4	Analyse the AC Machine drives and their control strategies using suitable power electronic topologies.
CLO5	Summarize the working principles, control and applications of special machine drives.

Fundamentals of electric drives, basic components, advantages, closed loop control, speed, torque conventions, steady state equilibrium, and determination of motor power rating. Introduction to power electronics, Power Diode, SCR, BJT, MOSFET and IGBT, Uncontrolled and controlled rectifiers, loads, freewheeling diodes. Choppers, Inverters and AC-AC converters. DC motors, operating principles, torque speed characteristics, speed control concepts, Control of DC motor using choppers and controlled rectifiers. AC motors, three phase induction motors, operating principles, torque speed characteristics, speed control, single phase induction motors, synchronous motors, linear induction motors, PM synchronous motors, BLDC motors, switched reluctance motors and synchronous reluctance motors. Servo motors, stepper motors and universal motors.

Self-study:

1. Advanced Power Semiconductor devices: SiC and GaN and their advantages and applications.
2. Advanced Motors: Axial motors, Hub Motors

References:

1. Gopal K. Dubbey, *Fundamentals of Electric Drives,* (2e), Narosa Publishers, 2010.
2. Bimbra P.S., *Power electronics*, (3e), Khanna Publishers, 2010.
3. P. C. Sen, *Principles of Electrical Machines,* (3e), Wiley, 2020.
4. R. Krishnan, *Electric Motor Drives Modeling, Analysis, and Control*, (2e), Prentice Hall, 2012.
5. L. Umanand, *Power Electronics: Essentials & Applications*, Wiley 2009.

MTE **: MANUFACTURING TECHNOLOGY [3 0 0 3]**

At the end of the course the students will be able to:

CLO1	Comprehend the Fundamentals, Basic Processes, and various common aspects of Manufacturing.
CLO2	Select suitable 3D printing technique to design, analyse and build required functional parts.
CLO3	Demonstrate CNC programming, skills to differentiate various traditional and non-traditional machining techniques.
CLO4	Illustrate various additive manufacturing techniques for realizing components in real time.

Over View of Manufacturing process: Types of manufacturing processes and their operating principles, tooling, quality issues in manufacturing processes. Computer Numerical Controlled Machines tools: Components of CNC Machines, Construction details of CNC machines, Machine structure, Guide ways, Spindle, Measuring systems, Drives and Controls. Configuration of CNC system, Interfacing, Monitoring, Diagnostics, Compensations for machine accuracy, Adaptive control CNC systems. Testing of CNC machines. Advanced Manufacturing techniques: Abrasive Jet Machining, Ultrasonic Machining, Electro Chemical Machining, Laser and electron beam machining, Electro Discharge Machining. Additive Manufacturing: Process Chain for Additive Manufacturing Processes, Benefits of Additive Manufacturing. Rapid Prototyping Data Formats Non – Manifold Conditions. Liquid Based Process. Application in design, engineering, analysis and planning, Application in manufacturing and tooling, automotive, biomedical industry, Application in jewellery, coin industry.

Self-study:

Different applications based on manufacturing processes and case studies on methodologies involving various techniques for prototyping.

References:

1. C.K. Chua, K.F. Leong, C.S. Lim, *Rapid Prototyping: Principles and Applications,* (3e), 2010.
2. Gibson, I, Rosen, D W., and Stucker, B., *Additive Manufacturing Methodologies: Rapid Prototyping to Direct Digital Manufacturing*, Springer, 2014.
3. Kalpakajain, *Manufacturing Engineering and Technology*, (4e), Addison Wesley, New York, 2014.

4. Hans B. Kief, Helmut A. Roschiwal, CNC Handbook, (1e), McGraw-Hill Education, 2012.
Jagadeesha T, *Non-Traditional Machining Processes*, I K International Publishing House Pvt. Ltd, 2016.

MTE *** HYDRAULICS AND PNEUMATICS SYSTEMS [3 0 0 3]

At the end of the course the students will be able to:

CLO1	Discuss the fundamental concepts of fluid power recognize the various types of fluid flow problems encountered in practice.
CLO2	Explain the working, utilization, standard notations of various power generating and distributing elements for a hydraulic and pneumatics systems.
CLO3	Solve job scheduling and inventory management problems using appropriate techniques.
CLO4	Describe the operating principle of various actuators, valves of hydraulics and pneumatics systems.
CLO5	Outline the concepts of Electro – pneumatic system, sensors and their application in various automation systems.

Introduction to pneumatic systems: Structure and signal flow, Applications of pneumatic systems, Pneumatic power pack, Air reservoir, Air generation and Distribution, different types of compressor, Constructional details and working of filter, lubricator and pressure regulator. Actuators and Control valves: Single acting and double acting cylinders, Air motor and types, comparison between Air and electric motor, Various types of poppet valve, spool and rotary direction control valves, Check valves, Dual pressure valve, shuttle valves, Time delay valves, Pressure sequence valves. Manual pneumatics: Traverse time diagram, Design of pneumatic circuits using classic, Cascade and Step counter approaches. Electro-pneumatics components and sensors: Electrically actuated direction control valves, Relay control systems, Application circuits using electronic sensors. Logic circuit design using K-V mapping. Introduction to Hydraulic systems: Physical principles of oil hydraulics, Hydraulic power pack, Types of hydraulic pumps: Hydraulic actuators, valves and accessories. Pressure control valves. Hydraulic circuits: Regenerative, meter in, meter out, bleed off, Sequencing, pressure reducing circuits, electrohydraulic circuits.

References:

1. Anthony Esposito, *Fluid power with applications*, Pearson Education, 2003.
2. Andrew A. Parr, *Hydraulics and Pneumatics*, Elsevier Science & Technology Books, (3e), 2011.
3. Scholz D., *Proportional Hydraulics*, Festo Didactic GMBH & Co, Germany, 2002.
4. Majumdar S.R., *Pneumatic Systems - Principles and Maintenance*, Tata McGraw Hill, 2000.
5. Merkle D., Rupp K. and Scholz D., *Electrohydraulics Basic Level TP 601*, Festo Didactic

GMBH & Co, Germany, 1994.

MTE ****: DRIVES, CONTROLS AND MODELLING LAB [0 0 3 1]

At the end of the course the students will be able to:

CLO1	Model and simulate DC excited series RL & RLC circuit using Analytical, Numerical and circuit approach.
CLO2	Select, model and control power converters for various applications.
CLO3	Acquire detail knowledge on DC and AC Machine Drives control using suitable power converters.
CLO4	Implement real-time control of DC and AC Drives using IGBT based power converters and recognize their limitations.
CLO5	Utilize the industrial drivers and software solutions and control them through programming to accomplish specific tasks in automation.

Modeling of RL and RLC circuits, Power Electronics. Closed loop PID control. DC Motor Modelling and Control. AC Induction Motor Control. Industrial PLC Based PMSM motor control. V/f Control of Induction Motor. PWM Based DC Motor Control. Advanced drives: BLDC, Switched Reluctance Motor, Stepper, Servo and Linear Motor Drives, AC Servo drives.

Self-study:

Selection of power semiconductor devices as per applications. Impact of PID gains on control systems, Applications of closed loop controls.

References:

1. *Drives and Control training system- Practice module*, BOSCH REXROTH manual, Germany 2011.
2. *Matlab Documentation*, Mathworks.
3. *PLC training practice module*, BOSCH REXROTH manual Germany 2011.
4. John W. Webb and Ronald A. Reiss, *Programmable logic controllers-Principle and applications*, (5e), PHI.
5. Hackworth and Hackworth F.D, *Programmable logic controllers- Programming Method and applications*, Pearson, 2004.

MTE ****: ROBOT OPERATING SYSTEM LAB [0 0 3 1]

At the end of the course the students will be able to:

CLO 1	Apply the knowledge of python, linux, C++, robot operating system package for robotics and autonomous systems.

CLO 2	Develop different robotic models using simulation tools, apply kinematic and dynamic models of robots for navigation
CLO 3	Use sensing and actuation systems applied to robotic systems, and the importance of using multiple sensors in robotic and autonomous systems in simulation and real mobile robots/industrial robots for automation
CLO 4	Develop algorithms for mobile robot navigation, as well as control of multi-axis manipulators.
CLO 5	Develop an application involving functional safety, health, ethical, management, legal, society, and environment as a team member or leader.
CLO 6	Evaluate various path planning algorithms in the form of technical report, oral presentation identifying the use of industry standards, safety, risk assessment and ethics.

Introduction to ROS2, Installation, Create ROS2 Workspace: Python and C++ Package, Object-Oriented Programming, ROS2 Nodes, Publisher/Subscriber, Custom, Experiments with Turtle Sim Package, Topics, Services, Actions, Parameters, Debug Tools in ROS2, Introduction to URDF, 3 axis manipulator design, Control of manipulator, 3 wheeled robot Design, Gazebo and RViz, Sensor Integration, Introduction to Moveit2, ROS2 Industrial Robots, Working with TurtleBot and UR5 using ROS2.

Self-study:

1. Basic knowledge of object-oriented programming in python or C++
2. Basic knowledge of robotics
3. Path planning algorithms, Coursera Course on Collaborative Robot Safety: Design & Deployment.

References:

1. Anis Koubâa, *Robot Operating System (ROS), the complete reference*, volume 1, Springer International Publishing, 2016.
2. Anis Koubâa, *Robot Operating System (ROS), the complete reference*, volume 2, Springer International Publishing, 2017.
3. Lentin Joseph, *Robot Operating System for absolute beginners*, Apress Media LLC, 2018.
4. Wyatt Newman, *A systematic approach to learning robot programming with ROS*, Chapman and Hall, 2017.
5. Joseph Howse, Prateek Joshi, Michael Beyeler, *OpenCV_Computer Vision projects with Python*, Packt Publishing, 2016.
6. Alvaro Morena, *Artificial Vision and Language Processing for Robotics*, Packt Publishing, 2019.
7. https://wiki.ros.org/

SIXTH SEMESTER

HUM ****: ESSENTIALS OF MANAGEMENT [2 1 0 3]

At the end of the course the students will be able to:

CLO 1	Identify the managerial plan used in the given business context
CLO 2	Prepare an organizational chart and develop human resource plan
CLO 3	Apply motivational and leadership theories in any given organizational context
CLO 4	Identify suitable controlling techniques to handle engineering projects
CLO 5	Differentiate ethical and moral practices in developing a business plan

Definition of management and systems approach, Nature & scope. The Functions of managers, Principles of Management. Planning: Types of plans, steps in planning, Process of MBO, how to set objectives, strategies, policies and planning premises, Strategic planning process and tools. Nature and purpose of organizing, Span of management, factors determining the span, Basic departmentation, Line and staff concepts, Functional authority, Art of delegation, Decentralization of authority. HR theories of planning, Recruitment, Development and training. Theories of motivation, Special motivational techniques. Leadership – leadership behavior & styles, Managerial grid. Basic Control Process, Critical Control Points & Standards, Budgets, Non-budgetary control devices. Profit and Loss control, Control through ROI, Direct, Preventive control. PROFESSIONAL ETHICS - Senses of Engineering Ethics, Variety of moral issues, Types of inquiry, Moral dilemmas, Moral Autonomy, Kohlberg's theory, Gilligan's theory, Consensus and Controversy, Models of professional roles, Theories about right action, Self-interest, Customs and Religion, Uses of Ethical Theories. GLOBAL ISSUES - Managerial practices in Japan and USA & application of Theory Z. The nature and purpose of international business & multinational corporations, unified global theory of management, Entrepreneurship and writing business plans. Multinational Corporations, Environmental Ethics, Computer Ethics, Weapons Development, Engineers as Managers, Consulting Engineers, Engineers as Expert Witnesses and Advisers, Moral Leadership, Code of Conduct, Corporate Social Responsibility.

References:

1. Harold Koontz & Heinz Weihrich (2020), "Essentials of Management", McGraw Hill, New Delhi.
2. Peter Drucker (2004), "The practice of management", Harper and Row, New York.
3. Vasant Desai (2007), "Dynamics of entrepreneurial development & management", Himalaya Publishing House.
4. Poornima M Charantimath (2006), "Entrepreneurship Development", Pearson Education.
5. Mike W. Martin & Ronald Schinzinger (2003), "Ethics in engineering", Tata McGraw Hill, New Delhi.
6. Govindarajan M, Natarajan S, & Senthil Kumar V S (2004), "Engineering Ethics", Prentice Hall of India, New Delhi.

7. R. S. Nagarazan. (2004), “A text book on professional ethics and human values”, New age international publishers, New Delhi.

MTE ****: ENERGY AND HEAT TRANSFER [3 0 0 3]

At the end of the course the students will be able to:

CO1	Calculate the work, heat transfer and efficiency for the processes and refrigeration cycles using the basic principles of thermodynamics.
CO2	Interpret the modes of heat transfer and calculate the heat transfer rate in plane walls and composite walls using the basic laws governing the conduction and convection heat transfer.
CO3	Apply the fundamentals of heat transfer to evaluate the performance of Fins and other heat exchangers used in electronic equipment
CO4	Describe properties of fluids and apply flow characteristics equations for real fluid systems.
CO5	Apply laminar flow equations and boundary layer concepts to access the flow through pipes in parallel and series.
CO6	Apply the knowledge of risk mitigation, and safety while the problems the heat exchanger for industrial applications.

Properties of pure substances and ideal gases, First and second laws of thermodynamics, Energy conversion by cycles, Power-absorbing and power producing cycles. Fluids and Their Properties, Fluid Pressure and Its Measurement, Hydrostatics, Buoyancy and Floatation, Kinematics of Fluid Flow, Venturiemeter and Pitot Tube, Small and Large Orifices, Applications of the Momentum equation, Flow Through pipes, Heat Transfer: Introduction to heat transfer, General Law of Heat Conduction, Steady state one dimensional heat conduction with and without heat generation, Heat Transfer from Extended Surfaces, Heat Transfer by Forced convection and Free convection, Radiation, Heat Exchangers, Cooling of Electronic equipment.

Self-study:

Risk mitigation, and safety for Vapor compression cycle and heat exchangers for refrigeration and thermal power plants and industry.

References:

1. Cengel Y Al and Boles M A, *Thermodynamics, An Engineering Approach*, Tata Mc Graw Hill, 2003.
2. Michael J Moran, *Fundamentals of Engineering Thermodynamics*, Wiley India Pvt. Ltd., 2010.
3. Munson B R, Young D F and Okiishi T H, *Fundamentals of Fluid Mechanics*, John Wiley & Sons., Singapore, 2006
4. Kumar D. S, *Fluid Mechanics and Fluid Power Engineering*, Kataria S K and Sons, New

Delhi, 2010.
5. Yunus A. Cengel, *Heat Transfer: A Practical Approach*, Tata McGraw Hill Inc., New Delhi, 2005.

MTE****: AUTOMOBILE ENGINEERING [3 0 0 3]

At the end of the course the students will be able to:

CLO1	Classify different vehicle construction layouts, vehicle types based on size and types of wheel drive systems, automobile power systems.
CLO2	Apply the emission norms of BS4 and BS6 Engines for automobile industry
CLO3	Apply the different transmission systems and tyre for automobile components.
CLO4	Apply different steering and suspension systems for automobile applications
CLO5	Classify types of brakes, electrical components, air conditioning components and materials for automobile components.
CLO6	Apply the knowledge of industry standards, risk mitigation, and safety while designing the Automobiles

Introduction to automobile engineering: vehicle construction and layouts, chassis, frame and body. Vehicle power supply systems. Transmission systems, clutch types & construction, gear boxes- Hydrodynamic Clutches, Torque Converter. Heating and air conditioning systems. Steering geometry and types of steering gear box, power steering, types of front axle, types of suspension systems, pneumatic and hydraulic braking systems. Desirable tyre properties, conventional tubed & tubeless tyre. Noise vibration and harshness in automobiles, Fundamentals of regenerative braking. Bearing and lubrication systems, environmental management and service information systems. Electrical and lighting systems, Industrial Fabric, ergonomics and safety standards in automotive industry.

References:

1. Jack Erjavec, Rob Thompson, *Automotive Technology - A Systems Approach*, Cengage (7 e), 2018.
2. Richard Stone, Jeffrey K. Ball, *Automotive Engineering Fundamentals*, SAE International (1e), 2004.
3. Trelle Borg, *Automotive Vibration Control Technology: Fundamentals, Materials, Construction, Simulation, and Applications* (1e), Vogel Business Media GmbH & Co. KG, 2015.
4. Kripal Singh, *Automobile Engineering* (4e), Vol-1 and 2, Standard Publishers, Delhi, 2011.
5. Robert Fischer, Ferit Küçükay, Gunter Jürgens, Rolf Najork, Burkhard Pollak, *Automotive transmission book* (4e), Springer International Publishing Switzerland 2015.

MTE ****: HYDRAULICS LAB [0 0 3 1]

At the end of the course the students will be able to:

CLO1	Apply the understanding of the structure, working principles of various hydraulics valves, and safety-risk assessment.
CLO2	Develop Electro-Hydraulics systems based on given application.
CLO3	Develop Proportional Hydraulic Systems based on given application.
CLO4	Design Electro/Proportional Hydraulics Systems based on self-defined applications
CLO5	Build a code of conduct by understanding the basics of laboratory management involving safety and ethics.

Working principles of hydraulic pumps, hydraulic motors, pressure switch, pressure reducing valve, accumulator, proximity switch, throttle valves, pressure compensated flow control valves and direction control valves. Rigging of manual and electro hydraulic circuits using above components. Working principle of Proportional direction control valve, Proportional pressure relief valve, command value module, proximity switches. Rigging of proportional hydraulic circuits using above components.

References:

1. *Industrial Hydraulics Trainee's manual,* BOSCH REXROTH manual, Germany 2011.
2. *Proportional valve technology Trainee's Manual* BOSCH REXROTH manual, Germany 2014

MTE **: IIOT LAB [0 0 3 1]**

At the end of the program the students will be able to:

CLO1	Examine problems related to communication protocols and the concepts of subnetting, for processes related to Industrial automation.
CLO2	Develop simulations for Computer networks using Computer Networking software.
CLO3	Develop programs for Radio and Wi-Fi based communication tasks using microcontrollers and booster packs.
CLO4	Develop programs for IIoT applications using microcontrollers, sensor hubs and AI software.
CLO5	Devise a minor project on any IIoT application by implementing the principles learnt in the course

Computer Networking fundamentals. Simulation of network devices viz., hub, switch and router using Cisco packet Tracer. Simulation of IIoT environment using Cisco Packet tracer. Operation of MSP432 microcontroller from TI. Interfacing of communication booster packs for Wi-Fi and Radio communication. Sensor data logger using STM32 microcontroller.

Self-study:
CourseEra course entitled: The Bits and Bytes of Computer Networking

References:

1. MSP432 Manual by Texas Instrumentation.
2. STM32 Manual by STMicroelectronics

MTE ****: PNEUMATICS LAB [0 0 3 1]

At the end of the program the students will be able to:

CLO1	Analyze the various fluid power generation and utilizing elements
CLO2	DDevelop manual pneumatic circuits for the given applications
CLO3	Develop the Electro-pneumatic circuits for industrial application.
CLO4	Develop closed loop pneumatic circuits to control various physical phenomenon in an industrial application
CLO5	Apply the knowledge of industry standards, risk mitigation, and safety while designing the pneumatic circuit for real-time applications.

Operations of various valves like directional control valves, flow control valves, pressure control valves and switches like pressure switches, proximity switches. Operations of timers and counters. Rigging of manual pneumatic and electro-pneumatic circuits using above valves and switches. Closed loop Pneumatics: Constant pressure control, Force control, Basics of PID control, Electro-pneumatic control with spring, Properties of electro-pneumatic control with spring.

Self-study:

Working of PID controller and its application in closed loop pneumatic circuits

References:
1. *Practice for Professional Pneumatics Trainee's manual*, BOSCH REXROTH manual, Germany 2011.
2. *Practice for Professional Electro-Pneumatics Trainee's manual*, BOSCH REXROTH manual, Germany 2011.
3. *Training system for pneumatics*, BOSCH REXROTH manual, Germany 2014

<u>SEVENTH SEMESTER</u>
There are five program electives and one open elective with total of 18 credits to be taught in this semester.

<u>EIGHTH SEMESTER</u>

MTE ****: INDUSTRIAL TRAINING

Each student has to undergo industrial training for a minimum period of 4 weeks. This may be taken in a phased manner during the vacation starting from the end of third semester. Student has to submit to the department a training report in the prescribed format and also make a presentation of the same. The report should include the certificates issued by the industry.

At the end of the course the students will be able to:

CLO1	Correlate the theoretical knowledge with the industry environment and get acquainted with the organizational structure and technical functions.
CLO2	Address the aspect of professional code of conduct followed in the industry.
CLO3	Appraise the best practices of safety, ethics and environmental standards followed in the industry.
CLO4	Enhance their learning by self-study and take suitable actions to reproduce their learning and developmental skills.

MTE ****: PROJECT WORK/PRACTICE SCHOOL

The project work may be carried out in the institution/industry/ research laboratory or any other competent institutions. The duration of the project work shall be a minimum of 16 weeks which may be extended up to 24 weeks. A mid-semester evaluation of the project work shall be done after about 8 weeks. An interim project report on the progress of the work shall be submitted to the department during the mid-semester evaluation. The final evaluation and viva-voice will be conducted after submission of the final project report in the prescribed form. Student has to make a presentation on the work carried out, before the department committee as part of project evaluation.

At the end of the course the students will be able to:

CLO1	Assess the work available in the literature related to the project to identify the limitations, risks and analyse associated safety, commercial, economic, environmental and societal impacts.
CLO2	Practice planning and time management in solving a problem, identifying the resources, estimating the project cost and risks, and complying with the regulations to demonstrate the professional skills to work effectively as a team.
CLO3	Develop the ability to adopt a methodological approach to solve the task/design/problem in mechatronics/ management stream by applying relevant mathematics, statistics, natural sciences and engineering principles, concepts and technologies.
CLO4	Enhance and adopt the computing/coding/statistical analysis, development of physical prototypes/hardware, experimentation and testing skills to achieve the set objectives.
CLO5	Document the work done with a technical report, adhering to scientific conventions and ethical guidelines.
CLO6	Communicate effectively the process and outcome of the project using audio-visual aids.

MINOR SPECIALIZATIONS

ELECTRIC VEHICLE TECHNOLOGY

MTE **** AUTOTRONICS [3 0 0 3]

At the end of the course the students will be able to:

CLO1	Correlate the theoretical knowledge of automotive electronics with the industry environment.
CLO2	Appreciate the concepts of electrical engineering and sensors technology in automobiles.
CLO3	Appraise the best practices of control mechanisms of a digital engine.
CLO4	Enhance the learning of vehicle motion control and autotronics lab modelling.

Fundamentals of automotive electronics, components for electronic engine management, sensors & actuators, digital engine control system, fuel control maps, SI engine management - injection system controls layout and working of monojetronic, l-jetronic and lh-jetronic, three way catalytic converter, CI engine management- fuel injection system, parameters affecting combustion, noise and emissions in CI engines, vehicle motion control and stabilization systems, vehicle motion control - adaptive cruise control, electronic transmission control, vehicle stabilization system - antilock braking system, traction control system, electronic stability program, onboard diagnosis system, future automotive electronic systems.

References:

1. Young, Griffitns, *Automobile electrical & electronic equipments*, Butterworths, London, 2010.
2. Wiliam B. Ribbens, *Understanding automotive electronics*, (5e), Newnes, Butterworth–Heinemann, 2009.
3. Robert Bosch, *Diesel engine management*, (3e), SAE Publications, 2004.
4. Robert Bosch, *Gasoline engine management*, (2e), SAE Publications, 2004.
5. Robert Bosch GmbH, *Automotive electrics and automotive electronics*, John Wiley and Sons 2008.

MTE **** HYBRID AND ELECTRIC VEHICLES [3 0 0 3]

At the end of the program the students will be able to:

CLO1	Compare and contrast the working principle, economic and environmental aspects of conventional, electric and hybrid automobile power train.
CLO2	Identify the components required for the hybrid and electrical power train by describing the characteristics of IC engine and Motor, power flow in hybrid and Electric Vehicles.
CLO3	Analyze various power sources for Electric Vehicles.

CLO4	Inspect various controls in Hybrid and Electric Vehicles.
CLO5	Identify hybrid vehicle types using Hybridness.

History of Hybrid and Electric Vehicles technology, Economics and Environmental aspects of vehicle technologies. Vehicle dynamics-vehicle resistance, dynamic equation, tire ground adhesion, maximum tractive effort, vehicle speed, transmission characteristics, vehicle performance. Hybrid and electric drive trains-configurations of electric vehicles, traction motor characteristics, basic concept of hybrid traction, hybrid drive train architecture – series, parallel torque and speed coupling. Electric propulsion unit: different motors, configuration and control of dc and induction motor drives, introduction to power modulators, control, advanced motor drives for EV: PMSM, BLDC, SRM and SyncRel Motor drives. Energy storage, regenerative breaking, classification of different energy management strategies, fundamentals of regenerative braking. Sizing the drive system- propulsion motor, sizing the power electronics, selecting the energy storage technology, communications, supporting subsystems. Hybridness, PHEV, Range extension vehicles, Control of Hybrid and Electric vehicles: ECU, CAN-bus, Vehicle Dynamics Control. Charging stations. Design of series hybrid drive train.

Self-study:

1. Case studies on types of Hybrid vehicles available in Market.
2. Case studies on Solar Powered vehicles.
3. New Sodium Ion Battery technology using SiC and GaN devices.

References:

1. Mehrdad Ehsani, *Modern Electric, Hybrid Electric and Fuel Cell Vehicles- Fundamentals, Theory and Design*, (3e), CRC Press, 2018.
2. Iqbal Hussein, *Electric and Hybrid Vehicles-Design Fundamentals*, (2e), CRC Press, 2010.
3. Gianfranco Pistoia, *Electric and Hybrid Vehicles - Power Sources, Models, Sustainability*, (2e), CRC Press, 2010.

MTE ****: VEHICLE DYNAMICS [3 0 0 3]

At the end of the course the students will be able to:

CLO1	Analyze the effect of forces in longitudinal direction during acceleration and braking of a vehicle under dynamic condition.
CLO2	Evaluate the forces, loads acting on an automobile tire and its relevance to vehicle performance.
CLO3	Assess the effect of forces in lateral direction on performance of the vehicle
CLO4	Formulate the mathematical model to understand the vertical dynamics of a vehicle
CLO5	Implement industrial standards and the fundamental concepts involved in automotive safety in analysing the dynamics of vehicle

Introduction to Vehicle System Dynamics: Theoretical background on Vehicle Dynamics and control, Fundamental approach to Vehicle modelling. Longitudinal dynamics: Vehicle Load Distribution – Acceleration, Brake Force Distribution, Braking Efficiency and Braking Distance, Braking, Semi-Trailer. Tire Mechanics: Introduction, Mechanical Properties of Rubber, Slip, Grip and Rolling Resistance, Tire Construction and Force Development, Contact Patch and Contact Pressure Distribution, Tire Brush Model, Lateral Force Generation – Ply Steer and Conicity, Tire Models – Magic Formula, Classification of Tyre Models, and Combined Slip. Lateral Dynamics: Introduction, Bicycle Model, Stability, and Steering Conditions, Effect of road loads on Dynamics of Vehicle – Aerodynamics, rolling resistance, Total road load, Under-steer Gradient and State Space Approach, Parameters affecting vehicle handling characteristics, Subjective and Objective Evaluation of Vehicle Handling and Rollover Prevention. Vertical Dynamics: Introduction, Quarter Car Model, Half Car Model. Introduction to Automotive Safety: Basic concepts, risk evaluation, basic models, accident avoidance, occupant injury prevention, human simulation applications, crash testing, special design models, future vehicle safety.

Self-study:

Industrial standard related to automotive safety. Advancement in human comfort and safety in automobile

References:

1. Thomas D. Gillespie, *Fundamentals of Vehicle Dynamics*, SAE International 1997.
2. Reza N. Jazar, *Vehicle dynamics: theory and application*. Springer, 2017.
3. Hans B. Pacejka, *Tire and Vehicle Dynamics*, Elsevier, 2012.
4. George Peters, Barbara Peters, *Automotive Vehicle Safety*, CRC Press, 2002.
5. J Y Wong, *Theory of Ground Vehicles*, John Wiley & Sons Inc., 2001.

MTE ****: MODELLING OF HYBRID AND ELECTRIC VEHICLES [3 0 0 3]

At the end of the course the students will be able to:

CLO1	Examine types of Vehicle Propulsion systems and their powertrains.
CLO2	Model the components of Hybrid and Electric Vehicles.
CLO3	Apply suitable control strategies for Hybrid and Electric Vehicles.
CLO4	Model the Battery Systems for Hybrid and Electric Vehicles.

Introduction to Vehicle Propulsion and Powertrain Technologies: Objectives of vehicle propulsion control. Powertrain architecture and technologies. Importance of Powertrain Modelling and Models – Drivetrain. Motor design, modelling and simulation of drives for Electric Propulsion. Vehicle dynamics control. Modelling and Control of Battery Management Systems. Braking. Design and Control of Hybrid Electric Vehicles. Modelling and control of Fuel cell based EV.

Self-study

Case study on vehicle body drag coefficient modeling using FEM tools. Case study on Modeling of Hybrid and Electric Vehicle designs available in Market.

References:

1. Shuvra Das, *Modeling for Hybrid and Electric Vehicles Using Simscape*, Morgan & Claypool Publishers, 2021.
2. Tom Denton, *Electric and Hybrid Vehicles,* Taylor and Francis, 2020.
3. Mehrdad Ehsani, *Modern Electric, Hybrid Electric and Fuel Cell Vehicles- Fundamentals, Theory and Design*, (3e), CRC Press, 2018.
4. Gianfranco Pistoia, *Behaviour of Lithium ion batteries in Electric Vehicles: Battery Health, Performance, Safety, Cost*, (1e), Springer, 2018.
5. Amir Khajepour, Saber Fallah and Avesta Goodarzi, *Electric And Hybrid Vehicles Technologies, Modeling And Control: A Mechatronic Approach*, Wiley 2014.

INDUSTRIAL IoT SYSTEMS

MTE ****: DATABASE MANAGEMENT SYSTEMS [3 0 0 3]

At the end of the course the students will be able to:

CLO1	Appraise the role of database management systems in information technology applications within organizations.
CLO2	Devise relational algebra queries for real time applications
CLO3	Design E-R models for composite data base systems
CLO4	Design SQL queries for composite data base systems
CLO5	Compare the performance of different Data mining algorithms used in clustering and classification.
CLO6	Apply the data mining algorithms to propose solutions to complex research-oriented problems

Introduction: Database-System Applications, Relational Databases, Data Storage and Querying, Transaction Management, Database Architecture, Database Users and Administrators. Relational Model: Structure of Relational Databases, Database Schemas, Keys, Relational Query Languages, Relational Operations. Database Design and The E-R Model: SQL: SQL Data Definition, SQL Data Types and Schemas, Integrity Constraints, Basic Structure of SQL Queries, Set Operations, Aggregate Functions, Nested Subqueries, Additional Basic Operations Null Values, Atomic Domains and First Normal Form, Decomposition Using Functional Dependencies, Functional Dependency Theory, Algorithms for Decomposition, Decomposition Using Multivalued Dependencies. Transaction Management: Transaction Concept. Data mining: Introduction, Association rules mining, market based analysis, Apriori Algorithm, Partition Algorithm, Pincer –Search Algorithm, Dynamic item set counting algorithm, FP-tree growth Algorithm, PC Tree, Multilevel association rules, Clustering Techniques: Introduction, Clustering paradigms, Partitioning Algorithms, k – Medoid & k- means Algorithms, CLARA, CLARANS, Hierarchical Clustering, DBSCAN.

Self-study:

Topics related to Ethics in Database management from O'Keefe, O Brien, Ethical Data and Information Management: Concepts, Tools and Methods, (1e), Kogan Page, 2018.

References:

1. Silberschatz, Korth, Sudarshan, *Database System Concepts*, (7e), McGrawHill, New York, 2019.
2. Ramez Elmasri and Shamkant Navathe, Durvasula V L N Somayajulu, Shyam K Gupta, *Fundamentals of Database Systems*, (6e), Pearson Education, United States of America,2011.
3. Thomas Connolly, Carolyn Begg, *Database Systems – A Practical Approach to Design, Implementation and Management*, (4e), Pearson Education, England, 2005.
4. Peter Rob, Carlos Coronel, *Database Systems–Design, Implementation and Management*, (10e), Course Technology, Boston , 2013.
5. Jiawei Han and Micheline Kamber, *Data Mining Concepts and Techniques*, Morgan Kauffmann Publishers, (2e), 2008

MTE ****: CYBER SECURITY FOR INDUSTRIAL AUTOMATION [3 0 0 3]

At the end of the course, students will be able to:

CLO1	Apply a structured model in Security Systems Development Life Cycle (SecSDLC).
CLO2	Identify attack techniques and thwart intrusion attempts and other suspicious attempts to connect with the goal of gaining unauthorised access to a computer and its resources.
CLO3	Protect data and respond to threats that occur over the Internet.
CLO4	Perform risk analysis, security policies, and damage assessment for industrial applications.
CLO5	Implement various information security techniques in industrial applications through case study/ mini project.

Introduction to Security; Characteristics of Information; Components of an Information system; Systems Development Life Cycle; Security Systems Development Life Cycle; The Need for Security-Business Needs First; Threats; Attacks; Intruders; Intrusion Detection; Malicious Software – Types, Viruses, Viruses Countermeasures, Worms; Introduction to Database security; SQL Injection, Reliability and Integrity; Sensitive Data; Inference; Multilevel Databases; Proposals for Multilevel Security; Designs of Multilevel Secure Databases; Transport-level Security – Web Security Issues, SSL, TLS, PGP, S/MIME; IP Security – IP Security Policy, Encapsulating Security Payload, Internet Key Exchange; The Need for Firewalls; Firewall Characteristics; Types of Firewalls; Cyber Crimes and Hackers – Cyber Crimes, Hackers, Types of Attacks, Dealing with the Rising Tide of Cyber Crimes, Indian Cyber Law Offences, IEC 62243 Compliance.

References:

1. William Stallings, *Cryptography and Network Security: Principles and Practice*, (7e), Pearson, 2017.
2. Michael E. Whitman and Herber J. Mattord, *Principles of Information Security*, (6e), Centage Learning India Publication, 2017.
3. Charles P Pfleeger and Shari Lawrence Pfleeger, *Security in Computing*, (5e), PHI, 2015.
4. Joseph Migga Kizza, *A Guide to Computer Network Security*, (3e), Springer International Edition, 2015.
5. Global Cyber Security Alliance, *Quick Start Guide: An Overview of ISA/IEC 62443 standards; Security of Industrial Automation and Control Systems*. ISA. 2022.

MTE ****: INTERNETWORKING FOR INDUSTRIES [3 0 0 3]

At the end of the course the students will be able to:

CLO1	Correlate the theoretical knowledge of types of computer networks with practical network architectures.
CLO2	Appreciate the concepts of various communication protocols in the ISO/OSI model.
CLO3	Appraise the best practices of industrial communication prtocols.
CLO4	Enhance the learning of radio, infrared and satellite systems as LANs.

Introduction to Computer Networks**:** Types of networks, Types of transmission media, Concept and types of Multiplexing, Concept and types of Multiple Access techniques, Principles and types of Analog and Digital Modulation. ISO/OSI model: Physical layer: Types of cables, Types of connectors, Communication standards, Data-Link layer, Network Layer: IPv4, IPv6, Routing and Subnetting, Transport Layer: TCP, UDP. Networks in Industrial Process Automation: Introduction to networks in Industrial Process Automation, Networks and Protocols: AS-i, CAN, DeviceNet, Interbus, LON, Foundation Fieldbus, HART, PROFIBUS-PA, BACnet, ControlNet, IndustrialEthernet, Ethernet/IP, MODBUS, PROFIBUS-DP. Fiber Optic Communication: Principles of Fiber-Optic networks, Types of Fiber-Optic cables, Fiber-Optic Network design, Fiber cable installation and setup, Splices and Connectors, Inspection and testing. Radio, Satellite and Infrared Communication: Radio systems, Spread Spectrum techniques, Satellite LANs, Communication bands in satellite communication, Infrared Systems, Very fast Infrared.

References:

1. Liptak, B.G. (Ed.), *Instrument engineers' handbook, Vol. 3: Process software and digital networks*, (4e) CRC Press, Boca Raton, London, 2012.
2. Andrew S. Tanenbaum, *Computer Networks*, (5e), Prentice Hall of India Pvt. Ltd., 2011.
3. William Stallings, *Data and Computer Communications*, (8e), Prentice Hall of India Pvt. Ltd., 2014.
4. James F. Kurose, Keith W. Ross, *Computer Networking (A Top-Down Approach Featuring the Internet)*, (3e), Pearson Education, 2005.

5. Todd Lammle, *Cisco Certified Network Associate-Study Guide*, (2e), Sybex Inc. Publishing. 2000.

MTE ****: PRINCIPLES OF CRYPTOGRAPHY [3 0 0 3]

At the end of the course, students will be able to:

CLO1	Analyze and design classical encryption techniques and block ciphers to encrypt data.
CLO2	Choose a stream cipher cryptosystem for information encryption based on the complexities of modular arithmetic.
CLO3	Classify several kinds of public-key cryptosystems.
CLO4	Design cryptographic hash function-based encryption models in the application of message authentications and digital signatures.
CLO5	Implement various information security techniques in a wide range of applications through case study/ mini project.

Introduction – Security Goals, Attacks, Services and Mechanisms, Mathematics of Cryptography – Euclidean Algorithm, Modular Arithmetic, Fermat's and Euler's Theorems, Testing for Primality, The Chinese Remainder Theorem, Classical Encryption Techniques – Symmetric Cipher Model, Substitution and Transposition Techniques, S-DES, DES, 2DES, 3DES, Modes of Operation, AES - Structure, Round Functions, Key Expansion, Stream Ciphers, RC4, Public-Key Cryptosystems, RSA Algorithm, Diffie-Hellman Key Exchange, ElGamal Cryptographic System, Cryptographic Hash Functions – Applications, Hash Functions based on Cipher Block Chaining, Secure Hash Algorithm, SHA-3, Message Authentication Requirements, Message Authentication Functions, Digital Signatures.

References:

1. William Stallings, *Cryptography and Network Security: Principles and Practice*, (7e), Pearson, 2017.
2. Behrouz A. Forouzan and Debdeep Mukhopadhyay, *Cryptography and Network Security*, (3e), McGraw Hill, 2015.
3. Atul Kahate, *Cryptography and Network Security*, (3e), McGraw Hill, 2017.
4. Bruce Schneier, *Applied Cryptography*, (2e), John Wiley and Sons, Inc., 1996.

ROBOTICS AND AUTOMATION

MTE ****: ARTIFICIAL INTELLIGENCE FOR ROBOTIC VISION [3 0 0 3]

At the end of the course, students will be able to:

CLO 1	Analyse the feature extraction process for images for a wide range of industrial applications

CLO 2	Implement deep learning algorithms to compare various object detection approaches using software tools
CLO 3	Select appropriate algorithm and experimental tools to provide innovative solutions for segmentation in robotic and industry applications
CLO 4	Evaluate various generative adversarial networks for real time applications including its limitations.
CLO 5	Implement various deep learning algorithms with critical analysis in the form of technical report for robotics and industry automation applications.
CLO 6	Apply the knowledge of ethics, safety, and risk assessment with respect to data collection for a case study.

Image Formation, Linear Filtering, Correlation, and Convolution, Visual Features: Edge, Blobs, Corner Detection Algorithms, SIFT, SURF, HOG, Geometric transformation, Perceptron, Delta Learning Rule, Multi-layer Perceptron, Backpropagation, optimizers and Regularizers, data augmentation, Introduction to CNN, Evolution of CNN Architectures: AlexNet, ZFNet, VGG, Inception Nets, ResNets, DenseNets, Background of Object Detection, CNN for Recognition and Detection, R-CNN, Fast R-CNN, Faster R-CNN, YOLO, SSD, RetinaNet; CNNs for Segmentation: FCN, SegNet, U-Net, Mask-RCNN Review of RNNs; CNN + RNN Modls for Video Understanding, Deep Generative Models: GAN, Cycle-GANs, Progressive GANs, StackGANs, Pix2Pix Applications: Image Editing, Inpainting, Super-Resolution, Image Restoration, 3D Object Generation.

Prerequisite:

1. Probability, linear algebra, and calculus
2. Experience of programming in Python

References:

1. Goodfellow, Ian, Yoshua Bengio, and Aaron Courville. *Deep learning*. MIT press, 2016.
2. Nielsen, Michael A. *Neural networks and deep learning*. San Francisco, CA, USA: Determination press, 2015.
3. Adrian Rosebrock, *Deep Learning for Computer vision with Python- Starter Bundle*, Pyimagesearch, 2017.
4. Adrian Rosebrock, *Deep Learning for Computer vision with Python- Practitioner Bundle*, Pyimagesearch, 2017.
5. Szeliski, Richard. *Computer vision: algorithms and applications*. Springer Science & Business Media, 2010.
6. David, A., and Ponce Jean. *Computer vision: a modern approach*. Prentice Hall ,2002.
7. Richard Hartley, Andrew Zisserman, *Multiple View Geometry in Computer Vision*, 2004.

MTE ****: ROBOT DYNAMICS AND CONTROL [3 0 0 3]

At the end of the course the students will be able to:

CLO1	Evaluate the knowledge and understanding of Lagrange-Euler Dynamics, Force, Inertia, and Energy, Lagrange's Equations of Motion, Newton's equations of motion, Formulation of robot dynamics, State-Variable Representations, Dynamics of robots with actuators.
CLO2	Ability to derive and analyze the equations of motion for various robotic systems using Lagrange's equations and other mathematical models.
CLO3	Understanding of the principles and techniques of robot control, including Regulator problem, tracking problem, controllers, Set point Tracking, Actuator Saturation, Integrator Anti-windup Compensation, Quadratic Optimal control problem.
CLO4	Ability to design and implement various control strategies for robots, including Nonlinear dynamics and control – Lyapunov stability theorem, Robust control, Feedback-Linearization Controllers, Lyapunov Designs, Variable-Structure Controllers, Saturation-Type Controllers.
CLO5	Ability to analyze the stability of robotic systems using Lyapunov stability theorem and design control strategies to achieve desired stability.

Review of Robot Kinematics- Transformations: Joint/Task space, Forward Kinematics, Inverse Kinematics, Jacobians, Trajectory Generation, Serial and Parallel Kinematics. Robot Dynamics- Lagrange-Euler Dynamics, Force, Inertia, and Energy, Lagrange's Equations of Motion, Newton's equations of motion, Formulation of robot dynamics, State-Variable Representations, Dynamics of robots with actuators. Robot control problems – Regulator problem, tracking problem, controllers. Set point Tracking, Actuator Saturation, Integrator Anti-windup Compensation, Quadratic Optimal control problem. Nonlinear dynamics and control – Lyapunov stability theorem, Robust control, Feedback-Linearization Controllers, Lyapunov Designs, Variable-Structure Controllers , Saturation-Type Controllers.

Self-study:

RoboAnalyzer software model-based software to learn the Robotics concepts. http://www.roboanalyzer.com/

References:

1. Mark W. Spong, Seth Hutchinson, M. Vidyasagar, *Robot Modeling and Control*, (2e), John Wiley and sons, 2009.
2. Frank L. Lewis, *Robot Manipulator Control- Theory and Practice*, (2e), CRC Press, 2003.
3. Mark W. Spong, *Robot Dynamics and Control*, (2e), John Wiley and sons, 2009.
4. Yoshikawa, *Foundations of Robotics: Analysis & Control*, (1e), Prentice Hall India, 2009.

MTE **: ROBOT PATH PLANNING AND MOBILE ROBOTS [3 0 0 3]**

At the end of the course the students will be able to:

CLO 1	Illustrate about the fundamentals on Autonomous Mobile Robots and classification of different mobile robots and their applications on state of the art technologies implemented on Autonomous Mobile Robots.

CLO 2	Analyze various concepts which encompasses areas like trajectory planning, locomotion techniques, Principal of Ground Robots and Modelling of Motion for Wheeled mobile robots.
CLO 3	Illustrate programs on different kinematic models of wheeled mobile robots and Dynamics of Mobile robots along with Simulataneous localization and Mapping and path planning
CLO 4	Demonstrate different Path Planning algorithms with their methodologies and techniques spanning various algorithms on Map based searches, Configuration based decomposition of environments.

Autonomous mobile robots - Locomotion - Wheeled locomotion- Robot kinematics models & constraints, Mobile robot workspace. Configuration Space – Obstacles space, dimensions of configuration space, topology of configuration space, parameterization, transformations, Potential Functions, Gradient descent. Implementation in plane- computation, local minima problem. Algorithms – Analysis and complexity, running time, complexity, completeness. Visibility graph, Graph Search A*, Weighted A*, Anytime & Incremental Search D*, Road Maps - Generalized Voronoi Graph (GVG), GVG – transversality, connectivity, opportunist path planning.Cell Decomposition – Trapezoidal decomposition, Morse cell decomposition, Visibility based decomposition. Sampling Based Algorithms, Rapidly Exploring Random Trees (ERT), Control based planning, Manipulation planning, Optimal motion planning, Feedback motion planning. Motion Planning – Motion planning under kinematics and dynamic constraints, Trajectory planning, Non-holonomic constraints, Path planning, Combined path planning and control.

List of Experiments:

1. Implement Dijikstra’s algorithm for a mobile robot
2. Implement A* algorithm for a mobile robot
3. Extend A* algorithm to a C-space for 2 degree planar manipulator
4. Implement Probabilistic Road Maps for more than 3 degree of freedom manipulator
5. Implement Artificial Potential Functions for path planning.
6. Executing any one of the above mentioned algorithms for planning a path and then control a Lego robot to follow the path generated.
7.

Self-study:

Classification of different robots and their case studies with applications

References:

1. Fahimi, Farbod, *Autonomous robots: modeling, path planning, and control*. Vol. 107. Springer Science & Business Media, 2008.
2. H. Choset, K. M. Lynch, S. Hutchinson, G. A. Kantor, W. Burgard, L. E. Kavraki, S. Thrun *Principles of Robot Motion: Theory, Algorithms, and Implementations*, MIT Press, Cambridge, MA, 2005.
3. S. M. LaValle, *Planning Algorithms*, Cambridge University Press, Cambridge, UK, 2006.

MTE ****: SOFT ROBOTICS [3 0 0 3]

At the end of the course the students will be able to:

CLO1	To apply the principles of Bio robotics and biomimetics, and nature-inspired designs, and how they can be applied to the design of robotic systems.
CLO2	To evaluate the knowledge of 3D printing techniques on how they can be used to produce soft materials for hyper-elasticity, and finite element analysis.
CLO3	To analyse the concepts of soft actuators, soft sensors, and stretchable electronics, and how they can be used in soft robotic systems.
CLO4	To develop an understanding of the applications of bio-mimetics, including modelling of snake/earthworm, caterpillar, and other animals, and continuum mechanics.
CLO5	To apply the knowledge gained about case studies on wearable robotics, space robotics, deep-sea robotics, healthcare systems, and under-actuated robots.

Bio robotics, biomimetics, nature-inspired designs, materials for soft robot, biological analogy, Soft Actuators, Soft Sensors, Electroactive Polymer, Ionic Polymer Metal Composites, Shape Memory Alloy, Artificial Muscles based on Electric/Pneumatics, Thermal/Chemical Actuation , Introduction to 3D Printing, 3D printing of Soft Materials, Hyper-elasticity, Finite Element Analysis, Stretchable Electronics, Soft Electrical Materials, Soft Mechanical Composite Materials, Gradient of Material Stiffness, Mechanical Soft Materials, Pneumatic Artificial Muscles, Mathematical Modelling of Flexible Manipulator, Introduction to Euler Cautchy Elasticity Problem Hyper-redundant kinematic structures, Resolution of inverse kinematics, Mathematical formulation for animating flexible structure, Bio-mimetics (modelling of snake/earthworm, caterpillar etc), Continuum Mechanics, Eigenvalues and Eigenvectors, Geometric interpretation of eigenvectors, Cayley-Hamilton theorem, Principal Component Analysis, Singular Value Decomposition, ISO-Map Dimensional Reduction technique, Case Studies on wearable Robotics, Space Robotics, Deep-Sea Robotics, Healthcare Systems, Under-actuated Robots.

Self-study:

Continuum mechanics, SOFA software: https://www.sofa-framework.org/

References:

1. Matthew Borgatti, Kari Love, Christopher G. Atkeson, *MAKE: Soft Robotics – A DIY Introduction to Squishy, Stretchy, and Flexible Robots, 2018.*
2. Jog, C.S., Foundations and applications of mechan*ics: Volume I: Continuum mechanics*, Narosa Publishing House, 2007.
3. Alexander Verl, Alin Albu-Schaffer, Oliver Brock, Annika Raatz, *Soft Robotics Transferring Theory to Application*, Springer, 2015.
4. Jaeyoun (Jay) Kim, *Microscale Soft Robotics: Motivations, Progress, and Outlook*, Springer International Publishing, 2017.
5. Cecilia Laschi, Jonathan Rossiter, Fumiya Iida, Matteo Cianchetti, Laura Margheri, *Soft Robotics: Trends, Applications and Challenges*, Springer International Publishing, 2016.

MICRO AND NANO SYSTEMS

MTE ****: SEMICONDUCTOR AND VLSI SYSTEMS [3 0 0 3]

At the end of the course the students will be able to:

CLO1	Know the basic concept of the semiconductor device and its features
CLO2	Explain power device and packing system
CLO3	Learn various CMOS design technique
CLO4	Study the importance of CMOS used in micro and nano technology

Introduction to Semiconductor devices, Device Basic Structure and Characteristics, High current effects in diodes, Breakdown considerations for various devices, Schottky rectifiers.- P-i-N rectifiers Power BJTs, Parasitics in Power Transistors, Power MOSFETs, Thyristors , Power Insulated Gate Transistors, Heat transfer in power devices, device packaging. Basic MOS device. Overview of non-ideal behaviour of deep sub-micron MOS transistors. Current mirrors and current sources. Single stage amplifiers, differential amplifiers – small signal analysis, frequency response, noise. OTA circuits – differential pair, cascodes, folded-cascodes, two-stage OTAs. Stability, frequency compensation, CMRR, PSRR. Feedback. Fully differential op-amps, CMFB. Bandgap references. Output stages. Overview of CMOS device fundamentals (DC Characteristics, AC Characteristics, Processing overview).

Self-study:

1. Case study on VLSI technology and its appliction- MIT Lib,USA
2. NPTEL,EdX contents on semiconductor and VLSI

References:

1. Baliga,G.J., *Fundamentals of Power Semiconductor Devices*, Springer.
2. S.M. Sze, *Physics of Semiconductor Devices*, (2e), Wiley, 1981.
3. Behzad Razavi, *Design of Analog CMOS Integrated Circuits*, McGrawHill.
4. Willy M. C, *Analog Design Essentials*, Sansen, Springer
5. Gray, Hurst, Lewis and Meyer, *Analysis and Design of Analog Integrated Circuits*, Wiley.
6. Neil H.E. Weste, David Money Harris, Addison-Wesley, *CMOS VLSI design: A circuits and systems perspective*, Pearson.

MTE ****: SMART MATERIALS FOR MICRO AND NANO SYSTEMS [3 0 0 3]

At the end of the course the students will be able to:

CLO1	Comprehend the basic concept of the smart material features
CLO2	Analyse the processing of the thin films and smart material

CLO3	Explain the working principle of the material characterising instruments
CLO4	Analyse the mechanical features of the smart materials

Material Science: introduction, structure, defects, bonds and bands, thermodynamics of material, kinetics, nucleation. Thin film nucleation: Atomic view of substrate surfaces, thermodynamic aspects of Nucleation, Kinetic processes in Nucleation and growth. Epitaxy: Lattice mismatch and defects in epitaxial film, epitaxy of compound semiconductors, High and low temp. methods of deposition. Structural and chemical characterization of films and surfaces. XRD, TEM, AFM, SEM. Inter diffusion: compound formation, phase transformation in thin film, metal, semiconductor reaction, mass transport in thin film. Mechanical properties of thin films: Mechanical testing and strength of thin films, analysis of internal stress,

Self-study:

1. NPTEL, IISC courses on smart materials
2. Case study on material characteristics

References:

1. Ephrahim Suhir, Y.C Lee, C. P Wong, *Micro- and Opto- Electronic Materials and Structures*.
2. Kasturi L. Chopra, *Thin Film Phenomena*.
3. Kasturi L. Chopra, Indrajeet Kaur, *Thin Film Device Applications*.
4. Milton Ohring, *The Materials Science of Thin Films*.
5. Klaus K. Schuegraf, *Hand book of thin films deposition processes and techniques; Principles, methods, equipment, and application*.
6. O. S. Heaven, *Thin Film Physics*.

MTE **: DESIGN OF MICRO AND NANO DEVICES [3 0 0 3]**

At the end of the course, students will be able to:

CLO1	Analyze and design of microsensors, biological and chemical sensors.
CLO2	Appreciate the design and construction of microactuators.
CLO3	Classify various interfacing methods used in design of micro and nano devices.
CLO4	Appreciate the case studies of micro and nano devices in various applications.

Introduction and historical background, Microsensors : Sensors and characteristics, Integrated Smart sensors, Sensor Principles/classification-Physical sensors (Thermal sensors, Electrical Sensors, tactile sensors, accelerometers, gyroscopes , Proximity sensors, Angular displacement sensors, Rotational measurement sensors, pressure sensors, Flow sensors, MEMS microphones etc.), Chemical and Biological sensors (chemical sensors, molecule-based biosensors, cell-based biosensors), transduction methods(Optical, Electrostatic, Electromagnetic, Capacitive, Piezoelectric, piezoresistive etc.), Microactuators : Electromagnetic and Thermal microactuation, Mechanical design of microactuators, Microactuator examples,-microvalves, micropumps, micromotorsMicroactuator systems : eg. Ink-Jet printer heads, Micro-mirror TV Projector. Introduction to interfacing methods: bridge circuits, Programmable gain instrumentation amplifiers, A/D and D/A converters, microcontrollers Applications and case studies: Microsensors and actuators in environmental sensing, RF/Electronics devices, Optical/Photonic devices, microsensors for space applications, MEMS sensors in navigation systems, radiation sensors, Medical devices, Bio-MEMS

References:

1. M.-H. Bao, *Micromechanical Transducers: Pressure sensors, accelrometers, and gyroscopes*, Elsevier, New York, 2000
2. Richard S. Muller, Roger T. Howe, Stephen D. Senturia, Rosemary L. Smith, and Richard M. White, *Microsensors*, IEEE Press, IEEE Number PC 0257-6, ISBN 0-87942-254-9, New York, 1991.
3. William Trimmer, *Micromechanics and MEMS: Classic and Seminal Papers to 1990*, IEEE Press, IEEE Number PC4390, ISBN 0-7803-1085-3, New York.
4. Beckwith T. G., Margoni R. D., Lienhard J. H., *Mechanical Measurements*, New York: Addison-Wesley Pub. Co, 1995
5. G. K. Ananthasuresh, K. J. Vinoy, S. Gopalakrishnan, K. N. Bhat, and V. K. Aatre, *Micro and Smart Systems*, Wiley-India, 2010.

MTE ****: FABRICATION AND TESTING OF MICRO SYSTEMS [3 0 0 3]

At the end of the course, students will be able to:

CLO1	Analyze and design of CMOS devices using fundamental principles.
CLO2	Appreciate the concepts of ion implantation.
CLO3	Classify various advanced technologies pertaining to SOI MOSFETs.
CLO4	Appreciate the case studies of emerging research devices and architectures.

Classical scaling in CMOS, Moore's Law, Clean room concept, Material properties, crystal structure, lattice, Growth of single crystal Si, Cleaning and etching, Thermal oxidation, Dopant diffusion in silicon, Deposition & Growth (PVD, CVD, ALD, epitaxy, MBE, ALCVD etc.),Ion-implantation, Lithography (Photolithography, EUV lithography, X-ray lithography, e-beam lithography etc.), Etch and Cleaning, CMOS Process integration, Back end of line processes (Copper damascene process, Metal interconnects; Multi-level metallization schemes), Advanced technologies(SOI MOSFETs, Strained Si, Silicon-Germanium MOS, metal semiconductor source / drain junctions, High K, metal gate electrodes and work function engineering, Double gate MOSFETs, FinFETs, TunnelFETsetc..) , emerging research devices and architectures (Nanowire FETs, CNT FETs, Graphene transistors, Organic FETs)

References:

1. James Plummer, M. Deal and P.Griffin, *Silicon VLSI Technology*, Prentice Hall Electronics

2. Stephen Campbell, *The Science and Engineering of Microelectronics*, Oxford University Press, 1996
3. S.M. Sze (Ed), *VLSI Technology*, (2e), McGraw Hill, 1988.
4. C.Y. Chang and S.M.Sze (Ed), *ULSI Technology*, McGraw Hill Companies Inc, 1996.

PRECISION AGRICULTURE TECHNOLOGY

MTE ****: SMART FARMING MACHINERY [3 0 0 3]

At the end of the course the students will be able to:

CLO1	Analyze the needs of different farming operations and design smart machinery that can automate tasks, monitor crops, and collect data.
CLO2	Implement sensing and control systems for smart machinery, such as sensors for soil moisture, temperature, and humidity, and actuators for precision spraying and seeding.
CLO3	Evaluate the performance of smart machinery in terms of efficiency, productivity, and cost-effectiveness, and compare it with traditional farming methods.
CLO4	Apply smart farming machinery to real-world scenarios, such as precision agriculture, livestock management, and environmental monitoring.
CLO5	Design, implement, and evaluate smart farming machinery for real-time application through case study / mini project.

Importance of agriculture as an industry in the context of shortage of quality food and resources, soil properties and their importance, soil fertility and essential plants nutrients. Soil-water-plant relationship, types of horticultural crops and its life cycle; Working principles of tools and machinery associated with soil preparation for variety of crops, principles of sowing and cultivation equipment, mechanically and electronically controlled fertilizer supply and pesticide spraying machines, machinery for horticultural crops protection and weed control; Introduction to climate controlled agriculture, Plant response to greenhouse environment, materials, planning and design of greenhouses, Instrument for measurement: pH, Electrical conductivity, gas analysis, humidity, leaf area, chlorophyll content and soil moisture & temperature, automatic control of temperature, moisture, air, smart irrigation systems, hydroponics technology. Working principles of harvesting machinery for various crops, Material handling equipment, conveyer and elevators, their working principle and selection**;** Grain drying equipment: deep bed dryer, flat bed dryer, tray dryer, fluidized bed dryer, re-circulatory dryer and solar dryer.

Self-study:

Agriculture robots, IoT and cloud computing in agriculture, integration of smart farm machinery and internet of things for precision agriculture.

References:

1. R.K. Sharma, A.K.Soni, R. Bhagat, N. Pandey and V.K. Pandey, *Basics of Agriculture for Engineers*, Daya Publishing House, New Delhi, 2014.
2. *Farm Power and Machinery* ICAR e-Course.
3. Sanjay Kumar, *Farm Power \and Machinery*, Kalyani Publications, 978-9327287257, 2018.
4. Cecilia Stanghellini; Bert Van 't Ooster; Ep Heuvelink, *Greenhouse Horticulture Technology for Optimal Crop Production*, ISBN: 978-90-8686-329-7, Wageningen Academic Publishers, 2019.
5. Basavaraj; Srigiri, D.; P.R., Jayan, *Textbook Of Farm Machinery And Power Engineering*, New India Publishing Agency, 2019.
6. Amalendu Chakraverty, Arun S. Mujumdar, Hosahalli S. Ramaswamy, *Handbook of Postharvest Technology: Cereals, Fruits, Vegetables, Tea, and Spices*, CRC Press, 2003.
7. Prabhat K. Nema, Barjinder Pal Kaur, Arun S. Mujumdar, Drying Technologies for Foods, Fundamentals and Applications, CRC press ,2019.

MTE ****: ROBOTICS AND AUTOMATION IN AGRICULTURE [3 0 0 3]

At the end of the course the students will be able to:

CLO1	Describe the fundamental concepts of robotics, including general robotic architecture, sensors, drive systems, and kinematics, and explain how they work together to perform robotic tasks.
CLO2	Apply the principles of task and trajectory planning to design and program robots that can execute specific tasks, such as harvesting crops using mechanical or soft grippers.
CLO3	Evaluate different types of drive systems used in robots, including electric and pneumatic drives, and design pneumatic control circuits using different types of control valves to achieve specific tasks.
CLO4	Analyze the principles of robotic vision systems, including thermal, depth, real-sense, and multi-spectral cameras, and integrate them with the robot's end-effector and drive system to perform complex tasks such as object recognition and tracking.
CLO5	Assess the working principles of agriculture drones, their classification, components, and their applications in agriculture for surveillance and pesticide application, and evaluate the ethical and societal implications of using drones in agriculture.

General robotic architecture, sensors, drive systems, kinematics, task and trajectory planning, robot controller and operating system; Classification and working of the electric and pneumatic drive used in robots, different types of pneumatic control valves and design of pneumatic control circuits; working principles of different types of end-effectors, Design and development of robotic end-effector for harvesting different crops; Working principals of thermal, depth, real-sense and multi-spectral cameras, capturing, processing and analysis of different images, integration of vision system with the end effector and drive system; Working Principles of drone, classification of agriculture drones, components of drones, application of drones in agriculture for surveillance and pesticide application.

Self-study:

Mobile robots, servo motors, actuators, robotic manipulators, machine vision.

References:

1. R Mittle, I Nagrath, *Robotics and Control*, McGraw Hill Education.
2. Joji P, *Pneumatic Controls*, John Wiley & Sons, 2018.
3. S.K. Pillai, *A First Course on Electrical Drives*, New Age Publishers.
4. Gareth J. Monkman, Stefan Hesse, Ralf Steinmann, Henrik Schunk, *Robot Grippers*, Wiley-VCH Verlag GmbH & Co. KGaA, 2006.
5. Inamuddin, Rajender Boddula, Abdullah M. Asiri, *Actuators: Fundamentals, Principles, Materials and Applications*, Scrivener Publishing LLC, 2020.
6. Berthold K.P. Horn, *Robot Vision*, MIT Press
7. K. R. Krishna, *Agricultural Drones A Peaceful Pursuit*, 2018.

MTE ****: FOOD PROCESS AUTOMATION [3 0 0 3]

At the end of the course the students will be able to:

CLO1	Apply knowledge of food quality evaluation, automated evaluation, food quality quantization, and process control to identify and solve typical problems in food quality inspection.
CLO2	Analyze data from various acquisition systems and employ pre-processing, static, dynamic, and image processing techniques for effective interpretation and decision-making.
CLO3	Construct theoretical and empirical models using static and dynamic modeling techniques such as linear statistical and ANN modeling, and predict product quality through sample classification and one-step-ahead prediction.
CLO4	Evaluate and optimize product process control using internal model control, predictive control, and neuro-fuzzy PDC techniques. Integrate product quality quantization and process control systems for optimal efficiency.
CLO5	Evaluate packaging machinery and systems, including vacuum, modified atmosphere, bottling, cartoning, and sealing machines, as well as aseptic and active/intelligent packaging systems. Assess emerging trends in the food industry, such as 3D food printing.

Introduction to Food quality, automated evaluation of food quality, food quality quantization and process control, typical problems in food quality evaluation, food odor measurement, continuous snack food frying quality; Sampling elaboration with examples, concepts and systems for data acquisition such as: ultrasonic signal acquisition, electronic nose data acquisition for food odor measurement, snack food frying data acquisition for quality process control, Image acquisition: elaboration with examples. Data analysis: Data pre-processing, Static data analysis, Dynamic data analysis, Image processing: Image segmentation, Image feature extraction etc.; Modeling strategies: Theoretical and empirical modeling, Static and dynamic modeling, Linear statistical modeling, ANN modeling etc. Prediction: Prediction and classification, Sample classification for grading, examples such as, based on linear statistical and ANN models, Electronic nose data classification for food odor pattern recognition, Snack food classification for eating quality evaluation based on linear statistical and ANN models, One-step-ahead prediction; Process control, Internal model control, Predictive control, Neuro-fuzzy PDC for product, Systems integration: Product quality quantization systems integration, product quality and process control systems integration, product quality quantization and process control systems development; Vacuum, Controlled and Modified atmosphere packaging systems, bottling machines, Cartooning systems, Seal and Shrink-packaging machine, Form, Fill and Sealing machine, Aseptic packaging systems, Retort packaging, Active and Intelligent packaging systems. Future trends in food industry: 3D food printing technology using: Extrusion based, inkjet based, Binder jetting, Selective laser sintering.

Self-study:

Food safety, Quality control system, data analysis, image processing, predictive modelling.

References:

1. Robberts Theunis C., *Food Plant Engineering Systems*, CRC Press, Washington, 2013.
2. Krammer, A. and Twigg, B.A. *Quality Control for the Food Industry*, Volume 2, Applications. The AVI Publishing Company, Westport, Connecticut.
3. Ranganna, S., *Hand book of Analysis and Quality Control for Fruits and Vegetable Products*, Tata McGraw Hill, New Delhi.
4. N. P. Padhy, S. P. Simon, *Soft Computing: With MATLAB Programming*, Oxford University Press, 2015.
5. Sudheer, K P. and Indira, V. *Post Harvest Engineering of Horticultural crops*. New India Publishing House.
6. Lal Giridhari, Siddappa and Tondon, *Preservation of Fruits and Vegetables*. ICAR, New Delhi, 2001.
7. Srivastava and Sanjeev Kumar. *Fruit and Vegetable Preservation: Principles and Practices*. Kalyani Publishers, 2008.

MTE ****: DIGITAL AGRICULTURE [3 0 0 3]

At the end of the course the students will be able to:

CLO1	Evaluate the advantages and limitations of using intelligent irrigation systems in agriculture, considering factors such as energy consumption and water efficiency
CLO2	Analyze the role of precision farming technologies in enhancing agricultural productivity, such as yield monitoring and mapping, and soil sampling and analysis
CLO3	Design and implement an IoT system for automatic farm management, including monitoring of climate conditions, crop management, and green house automation
CLO4	Assess the principles and applications of remote sensing technologies, including visual and digital image processing and ground water level monitoring, in agricultural and environmental investigations
CLO5	Evaluate the impact of ICT and digital tools in agriculture, including the adoption of AI-based farming and online marketing of agro-based products

Use of electrical energy in agriculture, electro-mechanical energy conversion, Electrical motors, pumps, Selection of motors for different farming applications, remote controlled intelligent irrigation systems, machine learning approach for efficient water usage, renewable energy sources. ; An Introduction to precision farming, GIS/GPS positioning system for precision farming, Yield monitoring and mapping, soil sampling and analysis, Computers and Geographic information systems, Precision Farming-Issues and conditions, Role of electronics in farm machinery for precision farming. ; Design and development of IoT system for fully automatic farm. Vertical forming, monitoring of climate conditions, green house automation, crop management, IOT for allied agriculture practices. ; Data acquisition systems, Test sites, Common measurements, Geologic investigations, Agriculture and Forestry investigations, Atmospheric investigation, visual image interpretation, digital image processing, Earth resource satellite, Ground water level monitoring.; The digital agriculture revolution, challenges of digital transformation, key drivers of digital agriculture transformation, Information and Communication Technology (ICT), Mobile Technology and its impact on agriculture and rural development, Artificial Intelligence (AI) based farming, adoption of ICTs and digital technologies in agriculture, Online Marketing of agro-based products, Strengthening Agricultural Market Access with ICT and Digital Tools.

Self-study:

Soil sensors calibration, irrigation scheduling, crop water estimation. Water quality management in irrigation etc.

References:

1. Singh Brahma and Balraj Singh, *Advances in Protected Cultivation*, New India Publishing Company, 2014.
2. Sharma P. *Precision Farming,* Daya Publishing House New Delhi, 2007.
3. Qin Zhang, *Precision Agriculture Technology for Crop Farming*, (1e), 2016.
4. Narendra Singh Rathore, Sunil Joshi, Naveen Choudhary, *Digital Technologies for Agriculture*, ISBN: 9789390591916, 2022.
5. Annamaria Castrignano, Gabriele Buttafuoco, Raj Khosla, Abdul Mouazen, Dimitrios Moshou, Olivier Naud, *Agricultural Internet of Things and Decision Support for Precision Smart Farming*, (1e), 2020.
6. Pradeep Tomar, Gurjit Kaur, *Artificial Intelligence and IoT-Based Technologies for Sustainable Farming and Smart Agriculture*, 2021.

PROGRAM ELECTIVES

MTE ****: ANTENNAS, RADAR AND NAVIGATION [3 0 0 3]

At the end of the course the students will be able to:

CLO1	Appraise the fundamental parameters used for antenna design.

CLO2	Correlate the different types of antennas based on shapes.
CLO3	Appreciate the concepts of radar and navigation systems.
CLO4	Assess the construction of various types of radar using software tools.
CLO5	Test the construction of sonar systems using software tools.

Antenna Fundamentals: Radiation mechanism and current distribution in thin wire antennas. Antenna fundamental parameters. Radiation Integrals and Auxilliary Potential Functions: Vector potential A and F and their solutions. Electric and magnetic fields of J and M sources. Far field pattern. Duality and reciprocity theorem. Types of Antennas. Introduction to RADAR and Navigation systems: Radar range equation. Minimum detectable signal, receiver noise, radar clutter, pulse repetition frequency. Doppler effect. Introduction to navigation systems and its types. Types of RADARs and SONAR: CW radar, FMCW radar. Moving target indicator (MTI) and pulse Doppler radar, Synthetic aperture radar. Radio altimeter, LORAN, DECCA, OMEGA, inland shipping aids, SONAR.

References:

1. Balanis C. A., *Antenna Theory, Analysis and Design* (4e), John Wiley and Sons, New Delhi, 2016.
2. Kraus J.D., *Antennas for all Applications* (4e), McGraw-Hill, 2001.
3. Balanis C. A., *Introduction to Smart Antennas* (1e), Morgan and Claypool Publishers, 2007.
4. Skolnic M., *Introduction to RADAR Systems* (2e), McGraw-Hill, 2010.
5. PeytonZ. and Peebles Jr., *Radar Principles* (2e), WileyIndia, 2009.

MTE ****: AUGMENTED REALITY AND VIRTUAL REALITY [3 0 0 3]

At the end of the course the students will be able to:

CLO 1	Gain a fundamental understanding of XR, including virtual reality continuum, characteristics of XR systems, perceiving digital information, advanced technologies of Virtual Reality, Augmented Reality and Mixed Reality.
CLO 2	Identify the opportunities for the application of XR in different stages of a project such as conception, design, and construction.
CLO 3	Apply Virtual Reality, Augmented Reality and Mixed Reality in the real-world scenarios during the project lifecycle.
CLO 4	Implement virtual reality-based robotic application using the Unity3D software tool.
CLO 5	Evaluate the existing solutions, limitations, and challenges of adopting Virtual Reality, Augmented Reality and Mixed Reality.
CLO 6	Explore broader implications of XR technologies, including the new opportunities they provide in industries.

Introduction - The three I's of Virtual reality, History of Virtual Reality, Early Commercial VR Technology, Classic Components of VR System. Multiple Models of Input and Output Interface in Virtual Reality: Gesture Interfaces, Three-Dimensional position trackers, Navigation and Manipulation Interfaces. Gesture Interfaces, Graphics, Three-dimensional Sound and Haptic Display, Graphic Displays, Sound Displays, Haptic Feedback,
Marker Tracking, Multiple Camera Infrared Tracking, Natural Feature Tracking by Detection, Incremental Tracking, Simultaneous Localization and Mapping, Outdoor Tracking,
Computer Architectures for VRs: The Rendering Pipeline, PC Graphics Architecture, Workstation Based Architectures, Distributed VR architectures, Geometric Modelling, Kinematic Modelling, Physical Modelling, Behavioral Modelling, Model management

References:

1. Burdea, Grigore C., and Philippe Coiffet. "Virtual reality technology." *International Journal of e-Collaboration* 2, no. 1 (2006): 61-64.
2. Schmalstieg, Dieter, and Tobias Hollerer. *Augmented reality: principles and practice*. Addison-Wesley Professional, 2016.
3. Parisi, Tony. *Learning virtual reality: developing immersive experiences and applications for desktop, web, and mobile*. " O'Reilly Media, Inc.", 2015.
4. Aukstakalnis, Steve. *Practical augmented reality: A guide to the technologies, applications, and human factors for AR and VR*. Addison-Wesley Professional, 2016.
5. Linowes, Jonathan. *Unity virtual reality projects*. Packet Publishing Ltd, 2015.

MTE **: AUTONOMOUS MOBILE ROBOTICS [3 0 0 3]**

At the end of the course the students will be able to:

CLO1	Apply various design choices for a robotics system
CLO2	Implement the right methods to control a mobile robot for a particular task.
CLO3	Integrate appropriate methods for sensing, cognition and actuation
CLO4	Implement perception, localization/navigation and control methods on a mobile robot
CLO5	Construct a planning roadmap and apply search techniques to compute a dynamically feasible, collision-free path between two locations.

Locomotion: Introduction, Legged Mobile Robots, Wheeled Mobile Robots. Mobile Robot Kinematics and Motion in Global Coordinates: Kinematic Models and Constraints, Mobile Robot Maneuverability, Mobile Robot Workspace, Dynamics of Quadrotor-Type Mobile Robots. Perception: Sensors for Mobile Robots, Feature Extraction. GNSS and Mobile Robot Localization: The Challenge of Localization: Localization-Based Navigation versus Programmed Solutions, Map Representation. Probabilistic Map-Based Localization. Global Navigation Satellite System. Planning, Navigation and Energy Considerations: Competences for Navigation, Navigation Architectures, Energy Limitations and Energetic Efficiency of Mobile Robots.

Self-study:

Different types of robots and their classification with case studies. Implementing various algorithms, in Mini projects

References:

1. Siegwart, Roland, Illah Reza Nourbakhsh, and Davide Scaramuzza. *Introduction to autonomous mobile robots*. MIT press, 2011.
2. Howie Choset, Kevin M Lynch, *Principles of Robot Motion*, MIT Press, 2005.
3. King Sun Fu, Gonzalez , *Robotics- control, sensing, vision, and intelligence,* McGraw-Hill, 1987.
4. Kagan, Eugene, Nir Shvalb, and Irad Ben-Gal, eds. *Autonomous mobile robots and multi-robot systems: Motion-planning, communication, and swarming*. John Wiley & Sons, 2019.

MTE ****: BIOMECHATRONICS [3 0 0 3]

At the end of the course the students will be able to:

CLO1	Interpret the fusion of mechatronics systems with human physiology or biological system for various applications
CLO2	Propose suitable sensors for gathering different biological signals
CLO3	Apply the concepts of different types of actuators for the development of biomechatronic systems
CLO4	Implement control strategies for biomechatronic systems
CLO5	Understand ethical, safety and risks involved in the development of biomechatronic systems through case studies

Introduction to biomechatronics, physiological systems- biochemical, nervous, cardiovascular, respiratory, musculoskeletal systems, fusion of bio and mechatronics, components of a biomechatronic system- sensors, actuators, controller, signal processor, few application areas; Sensors for capture of biological signals- surface electromyographic sensors, types of electrodes, intramuscular electromyography, electroencephalography, electrocardiography, electrooculography, nerve cuff, brain array, oxygen light sensors, oxygen consumption sensors; Chemical sensors to capture to stimuli produced by various chemical compounds, electric sensors, optical sensors, mechanical sensors, thermal sensors; Purpose of biomechatronic actuators- biological function replacement, augmentation or improvement, design goals of biomechatronic actuators, types of biomechatronic actuators-Motors, electromagnetic actuators, fluidic actuators, shape memory alloys, electroactive polymers, transmissions- linear, rotary, differential gear transmissions; Biomechatronic system model- Model based open loop control, model based closed loop control, case study-model based control of a biomechatronic system; Biomechatronic applications of brain-computer interface, upper limb prosthetic device, upper and lower extremity exoskeletons.

Self-study:

Neuro muscular physiology, Human gait

References:

1. Jacob Segil, *Handbook of Biomechatronics*, Academic Press, 2019.
2. Marko B. Popovic, *Biomechatronics*, Academic Press, 2019.
3. Graham m. Brooker, *Introduction to Biomechatronics*, Scitech Publishing, 2012.
4. Shane Xie, Wei Meng, *Biomechatronics in Medical Rehabilitation*, Springer, 2017.

MTE **: BUILDING AUTOMATION [3 0 0 3]**

At the end of the course the students will be able to:

CLO1	Appraise the fundamental parameters used for the design of intelligent buildings.
CLO2	Correlate the different types of network and communication protocols used in building automation.
CLO3	Appreciate the concepts of Building management systems and their architecture.
CLO4	Explain the components of HVAC systems used in BMS architecture.
CLO5	Assess the safety framework of BMS architecture and its applications.

Overview of Digital Controller: Data Form used in computers, Microcomputer, Input / Output Unit, Processor Operation and Software, Sensors, Actuator, I/O devices, Field Controllers. Network and Communication protocols: Networking basics, Types of Networks- Serial and Parallel Communication, RS232 and RS 485 Interfaces, MODBUS protocol overview, BACnet protocol overview. Introduction to Building Management Systems: Buildings and Energy Management, Different systems in a building. Introduction to HVAC, StruxureWare for Building Operation. General BMS architecture: Introduction to HVAC and Optimal control methods for HVAC Systems: Important components of HVAC, HVAC Control systems and Direct Digital Control, AHU, Chillers, Zones, Air Distribution Systems, Field Devices, Schneider Controllers (PLC's). Lighting control systems: Strategies for energy management and lighting. Security and Safety Control Systems: Access Control- Introduction, Basic Components, Controller / Panel, Credentials, Reader, Locking Device, How it works / Operations, Type of Card/Readers, Anti-Pass back, Power Requirements, Videos (Digital Video Recorder), Types of Camera, Fire Alarm Systems - Sprinklers. System integration and convergence: Need for integration, interoperability and protocols, BMS integration case studies, iBMS, Compatibility of different internet technologies and its application in BMS. Application of internet for Automation and Management: Web Based Automation, General Architecture, Web Enablement, Data Communication Energy Management: Overview on EMS, Energy Analysis/Audit. Green Buildings (LEED): Green Buildings Approach, Benefits of Green Buildings, Elements of Green Building Design, Leadership in Energy and Environmental Design (LEED), LEED Case Study.

References:

1. V. K. Jain , *Automation Systems in Smart and Green Buildings,* published by Khanna

Publishers, 2009.
2. Reinhold A, *Understanding Building Automation Systems: Direct Digital Control, Energy Management, Life Safety, Security/access Control, Lighting, Building Management Programs*, 2009.
3. Ronnie J. Auvil , *HVAC Control Systems* , (2e), 2007.
4. Thomas L. Norman, *Integrated Security Systems Design: Concepts, Specifications, and Implementation* (1e) by CPP PSP CSC 2007.
5. Benantar, Messaoud, *Access Control Systems: Security, Identity Management and Trust Models*, Springer publication, 2005.

MTE ****: CLOUD COMPUTING [3 0 0 3]

At the end of the course the students will be able to:

CLO1	Appraise the fundamentals of the cloud infrastructure and its services.
CLO2	Deduce the methodology used for cloud resource sharing and utilization.
CLO3	Appreciate the concepts of Cloud virtualization.
CLO4	Explain the components of Cloud security services.
CLO5	Assess the software used for Cloud computing.

Introduction, Cloud infrastructure, Cloud computing delivery models and services, Cloud computing at Amazon, The Google perspective, Microsoft Windows Azure, Application paradigms, Architectural styles of cloud computing, Cloud resource management and scheduling, Cloud resource virtualization, Types of virtualization, Understanding hypervisors, Virtual machine and its components, Resource management, Memory ballooning, Thin virtual provisioning, Storage tiering, Virtual LAN, VLAN trunking, VLAN tagging, Business continuity and cloud management, Virtual machine fault tolerance, Virtual machine replication methods, Cloud security, Virtual machine security, Access control and identity management, Cloud tools: Eucalyptus, OpenNebula/OpenStack, CloudSim.

References:

1. Dan C Marinescu, *Cloud Computing Theory and Practice*, Elsevier, 2013.
2. Rajkumar Buyya, Christian Vecchiola, S. Thamarai Selvi, *Mastering Cloud Computing*, McGraw Hill, 2017.
3. Anthony T. Velte, Toby J. Velte, Robert Elsenpeter, *Cloud Computing: A Practical Approach*, McGraw Hill, 2017.

MTE ****: DATA ANALYTICS AND MACHINE INTELLIGENCE [3 0 0 3]

At the end of the course the students will be able to:

CLO1	Appraise the fundamentals of data analytics and machine intelligence.
CLO2	Deduce the different algorithms used for machine learning frameworks.
CLO3	Deduce the different algorithms used for machine learning frameworks.
CLO4	Develop machine learning models for training, testing and validation of data pertaining to industrial automation using software tools.
CLO5	Develop deep learning models for training, testing and validation of data pertaining to industrial automation using software tools.

Statistical topics for Data science, Data- sources, privacy and confidentiality, samples vs. population. Data Pre-processing. Data Analysis and Visualization – descriptive, inferential statistics, data mining techniques. Grouping – Cluster Analysis. Market Basket Analysis, Association Analysis, Market Basket Analysis. Evaluation of Classification and Predictive performance, Forecasting models as application. Big-analytics software architectures. Introduction to Machine Learning, Mathematical Preliminaries, Supervised Learning, Model Selection, learning theory-bias/variance trade-off, Unsupervised learning-clustering, Dimensionality reduction techniques, Ensemble Models, Reinforcement learning. Deep Feedforward Networks: architecture design, Backpropagation algorithm, Regularization for Deep Learning, Dataset Augmentation techniques, Adversarial Training, Optimization for Training Deep Models, Convolutional Networks using Baseline models, Recurrent and Recursive Networks, Time Series Applications.

References:

1. Kevin P Murphy, *Machine Learning: A Probabilistic Perspective*, MITcPress, 2012.
2. Mehryar Mohri, Afshin Rostamizadeh, and Ameet Talwalkar, *Foundations of Machine Learning*, MIT Press, 2012.
3. Ian Goodfellow, Yoshua Bengio and Aaron Courville, *Deep Learning*, MIT Press 2016.
4. Glenn J. Myatt, Wayne P. Johnson, *Making Sense of Data I: A Practical, Guide to Exploratory Data Analysis and Data Mining*, (2e), John Wiley & Sons Publication, 2014.

Self-Study:

Course Era course entitled Python programming for All.

MTE **: DATA MINING AND VISUALIZATION [3 0 0 3]**

At the end of the course the students will be able to:

CLO1	Illustrate the fundamentals of data mining process.
CLO2	Deduce the different algorithms used for data classification process.
CLO3	Deduce the different algorithms used for mining of data streams.

CLO4	Develop data classification algorithms for data pertaining to industrial automation using software tools.
CLO5	Develop data mining algorithms for data pertaining to industrial automation using software tools.

The Statistical Data Mining Process: The Data Pre-processing Phase and Analytical Phase. The Basic Data Types: Non-dependency Oriented Data, Dependency Oriented Data, Association Pattern Mining, Data Clustering, Outlier Detection, Data Classification, Application Scenarios. Data Classification: Feature Selection for Classification, Filter, Wrapper and Embedded Models, Decision Trees, Rules based classifiers, SVM, Probabilistic Classifiers and Neural Nets. Mining Data Streams: Data Structures for Streams, Clustering Data Streams, Streaming Classification. Mining Text Data: Document Preparation and Similarity Computation, Specialized Classification Methods for Text. Mining Time-Series Data: Time-Series Preparation and Similarity, Time-Series Forecasting, Clustering, Classification and Outlier detection. Mining Discrete Sequences: Sequential Pattern, Sequence Clustering, Hidden Markov Models and Sequence Classification. Mining Web Data: Web Crawling and Resource Discovery, Search Engine Indexing and Query Processing, Ranking Algorithms, Recommender Systems, Web Usage Mining. Data Visualization, principles, tools and techniques.

References:

1. Charu Aggarwal, *Data Mining*, 2(e), 2015.
2. CR Rao, *Data Mining and Data Visualization*, 2(e), 2010
3. Claus O. Wilke, *Fundamentals of Data Visualization*, 2020, 2(e), O'Reilly.

MTE ****: DIGITAL MANUFACTURING [3 0 0 3]

At the end of the course the students will be able to:

CO1	Comprehend the Fundamentals, Basic Processes, and various common aspects of Manufacturing.
CO2	Identify the suitable control systems and networking protocols to interface hardwares and digital I/Os.
CO3	Develop a SQL querry to sortout the required information from the industrial databse using RDBMS architectures.
CO4	Demonstrate knowledge and understanding of work ethical aspects and technological risks in industries.
CO5	Develop digital twin and blockchain technologies to realise significance of digital manufacturing.
CO6	Inculcate ethical principles in teamwork, as well as industrial practises that are compatible with Digital Manufacturing.

Introduction to Digital manufacturing: Types of production systems. Needs of digital manufacturing, effective & efficient use of digital manufacturing (DM) tools. Scope of digital manufacturing in future. Flexible manufacturing systems, Computers in manufacturing industries, Key challenges, techniques, requirements, product life cycle management, Integration of CAD/CAM systems, Industrial control systems. Digital twin, architecture of digital twins, case studies on the application of digital twins in different domains.

References:

1. M.P.Groover, E.W.Zimmers Jr., *"CAD/CAM: Computer aided design and manufacturing",* Prentice-Hall of India Pvt. Ltd. 2001
2. P.N.Rao, *"CAD/CAM: Principles and Application",* Tata McGraw Hill 2005.
3. Tai Ran Hsu, *MEMS and Microsystems- Design and manufacturing*, Tata McGraw Hill, 2001
4. Marc J. Madou, *Fundamentals of microfabrication,2002*
5. https://www.coursera.org/learn/ethics-technology-engineering/.

MTE ****: DEEP LEARNING FOR COMPUTER VISION [3 0 0 3]

At the end of the course the students will be able to:

CLO 1	Analyse the feature extraction process for images for a wide range of industrial applications
CLO 2	Implement deep learning algorithms to compare various object detection approaches using software tools
CLO 3	Select appropriate algorithm and experimental tools to provide innovative solutions for segmentation in robotic and industry applications
CLO 4	Evaluate various generative adversarial networks for real time applications including its limitations.
CLO 5	Implement various deep learning algorithms with critical analysis in the form of technical report for robotics and industry automation applications.
CLO 6	Apply the knowledge of ethics, safety, and risk assessment with respect to data collection for a case study.

Image Formation, Linear Filtering, Correlation, and Convolution, Visual Features: Edge, Blobs, Corner Detection Algorithms, SIFT, SURF, HOG, Multi-layer Perceptron, Backpropagation, Introduction to CNN, Evolution of CNN Architectures: AlexNet, ZFNet, VGG, Inception Nets, ResNets, DenseNets, Visualization of Kernels; Backprop-to-image/Deconvolution Methods. Background of Object Detection, CNN for Recognition and Detection, R-CNN, Fast R-CNN, Faster R-CNN, YOLO, SSD, RetinaNet; CNNs for Segmentation: FCN, SegNet, U-Net, Mask-RCNN Review of RNNs; CNN + RNN Models for Video Understanding. Implementation using Deep Learning Libraries. Deep Generative Models: GAN, Cycle-GANs, Progressive GANs, StackGANs, Pix2Pix Applications: Image Editing, Inpainting, Super-Resolution, Image Restoration, 3D Object Generation.

Prerequisite

1. Basic course in Machine Learning
2. Deep Learning, or exposure to topics in neural networks
3. Probability, linear algebra, and calculus
4. Experience of programming in Python

References:

1. Goodfellow, Ian, Yoshua Bengio, and Aaron Courville. *Deep learning*. MIT press, 2016.
2. Nielsen, Michael A. *Neural networks and deep learning*. San Francisco, CA, USA: Determination press, 2015.
3. Szeliski, Richard. *Computer vision: algorithms and applications*. Springer Science & Business Media, 2010.
4. David, A., and Ponce Jean. *Computer vision: a modern approach*. Prentice Hall ,2002.
5. Bishop, Christopher. *Neural Networks for Pattern Recognition*, New York, NY: Oxford University Press, 1995.
6. Richard Hartley, Andrew Zisserman, *Multiple View Geometry in Computer Vision*, 2004
7. Mitchell, Tom. *Machine Learning*. New York, NY: McGraw-Hill, 1997

MTE ****: DESIGN OF MECHANICAL DRIVES [3 0 0 3]

At the end of the course the students will be able to:

CLO1:	Describe mechanical design process of mechanical drives through design of elements subjected to static and dynamic loadings.
CLO2:	Design bevel gear and worm gear for mechanical systems by identifying the static strength, dynamic strength.
CLO3:	Design Belt drives for power transmission.
CLO4:	Design Wire, chain and rope drives for mechanical systems by identifying the failure modes.
CLO5:	Design a mechanical breaks and clutchesfor a given application.

Introduction, bevel gear and worm gear, beam strength, dynamic load and wear load, heat dissipation and efficiency of worm gear, sliding contact bearings, lubricants, viscosity, bearing modulus, Sommerfield number, coefficient of friction, mechanism of film lubrication, eccentricity and minimum oil film thickness. Belt drives, power transmission, flat and V belts, power rating, V-flat drives, selection of belts and pulleys. Wire and rope drives - types & construction of wire ropes, loads & stresses in ropes, selection of wire ropes. Chain drives, chordal action, sprocket size and teeth, chain speed, selection of roller chains. Mechanical brakes - block brakes, band brakes, pivoted Shoe brakes, disc brake, torque capacity, heat dissipation, clutches, friction clutches, disc clutch, cone clutch, design projects.

Self-study:

Mechanical components used in robotic applications and design of these components used in industrial robots

References:

1. Shigley J. E. and Mischke C. R., *Mechanical Engineering Design, (5e)*, McGraw Hill Inc, New York, 2004.
2. Bhandari V. B., *Design of Machine Elements, (2e)*, Tata McGraw-Hill Publishing Company Limited, New Delhi, 2007.
3. Norton R. L., *Machine Design - An Integrated Approach, (2e)*, Prentice Hall Inc. New Jersy, 2004.
4. Juvenile R. C. and Marshek K. M., *Fundamentals of Machine Component Design, (3e)*, John Wiley and Sons, Inc, New York, 2000.
5. Mahadevan K. and Balaveera Reddy K., *Machine Design Data Hand Book, (4e)*, CBS Publishers and Distributors, New Delhi, 2014.

MTE **: ELECTRIC VEHICLES [3 0 0 3]**

At the end of the course the students will be able to:

CLO1	Compare and contrast the working principle, economic and environmental aspects of conventional, electric and hybrid automobile power train.
CLO2	Evaluate the vehicle performances by describing the dynamics of vehicle.
CLO3	Identify the components required for the hybrid and electrical power train by describing the characteristics of IC engine and Motor, power flow in hybrid and Electric Vehicles.
CLO4	Describe various energy sources and Hybridness in hybrid and electric configurations.

History of Vehicle technology. Case studies on vehicles. Economics and Environmental aspects of vehicle technologies – IC, Hybrid and EV. Overview of vehicle dynamics. Power Plants in vehicle technologies. IC Engine based vehicles – Fundamentals and types. IC Engine speed torque characteristics. EV Power plant characteristics. Electric Vehicle components: Battery, Motors and Auxiliary units. Types of Electric Vehicle configurations. Concept of regenerative braking and its significance in Electric Vehicles. Control of Electric Vehicles. Challenges in Electric Vehicles. Hybrid Vehicles – Series, Parallel, Series Parallel and Complex configurations. Fuel Cell based vehicles – Fundamentals and Future Potential of FCEV. Solar Powered EV. Case studies on types of Electric and Hybrid Vehicles.

Self-study:
Case studies on types of Electric and Hybrid Vehicles.

References:

1. Mehrdad Ehsani, *Modern Electric, Hybrid Electric and Fuel Cell Vehicles- Fundamentals, Theory and Design*, (3e), CRC Press, 2018.
2. Iqbal Hussein, *Electric and Hybrid Vehicles-Design Fundamentals*, (2e), CRC Press, 2010.
3. Gianfranco Pistoia, *Electric and Hybrid Vehicles - Power Sources, Models, Sustainability*, (2e), CRC Press, 2010.

MTE ****: EMBEDDED SYSTEMS AND RTOS [3 0 0 3]

At the end of the program the students will be able to:

CLO1	Utilize the basic functionality of embedded systems taxonomy.
CLO2	Analyze the concept of a multi-stage pipeline (3 and 5- stage), Memory, architectural features, and Memory-mapped peripherals.
CLO3	Compare various instruction sets of assembly language, setting up of GPIO, UART, TIMERS, and ADC for the ARM processor using Keil software.
CLO4	Apply the concept of OS and RTOS to implement the Semaphores, Tasks, and threads for real-time application.
CLO5	Analyze risk and safety assessment for embedded systems applications.

Introduction to embedded system, attributes and major application areas of ES, Processor and memory organization, Communication networks, ARM processor introduction, architectural inheritance, Architectural features of ARM Processor, instruction set, Pipelined architecture in ARM, THUMB instruction format, memory mapped peripherals, architectural features of ARM Cortex M3 and programming examples. Introduction To Real-Time Operating Systems, Tasks and Task states, Semaphores, Message queues, Mail boxes and pipes, Hard and Soft real time systems, scheduling considerations, Multicore real time systems. Case studies.

Self-study:

Risk and safety assessment for embedded systems.

References:

1. Wolf, Wayne, *Computers as Components- Principles of Embedded Computing System Design*, Morgan-Kaufmann, 2000.
2. Steve Furber, *ARM System-on-chip Architecture*, Pearson Education, 2000.
3. Andrew Sloss, Domnic Symes, Chris Wright, *ARM system Developer's Guide*, 1st edition.

MTE ****: ENGINEERING MATERIALS

At the end of the course, students will be able to:

CLO1	Analyze various types of solidification mechanisms and phase diagrams.

CLO2	Appreciate the types of alloys and composites and their usage.
CLO3	Classify the electrical, magnetic and optical properties of various types of materials.
CLO4	Appreciate the case studies of emerging research in material science and engineering.

Crystal structures, Miller indices, crystal imperfections, mechanism of solidification, nucleation and crystal growth, phases in solids, equilibrium diagrams, iron-Carbon systems, principle and objectives of heat treatment, TTT diagrams, electronic materials, deposition of thin films, insulators and dielectric properties, polarization in dielectrics, electrostriction, piezoelectricity, ferroelectricity, magnetic materials, magnetic dipole and moments, magnetization, super paramagnetic materials, applications of magnetic materials, photonic materials, refraction, reflection, absorption, emission phenomena.

References:

1. Donald R. Askeland and Pradeep P. Fulay, *The Science and Engineering of Materials*, Cengage learning publishers,*(6e)*,2011.
2. Lakhtin Yu., *Engineering Physical metallurgy and heat treatment*, MIR Publishers, Moscow, 1985.
3. Higgins R.A., *Engineering Metallurgy, (5e)*, ELBS, London,1983.
4. Avner S.H., *Introduction to Physical Metallurgy, (3e)*, McGraw Hill. Delhi, 2004.
5. Arzamasov, *Material Science*, MIR Publishers, Moscow. 1989.

MTE **: FRACTIONAL ORDER MODELLING AND CONTROL [3 0 0 3]**

At the end of the course, the students will be able to:

CLO1	Utilize various concepts of fractional order operators for industrial systems.
CLO2	Apply the knowledge of fractional order calculus to obtain the transfer function of the dynamics systems.
CLO3	Analyze the fractional order modeling for electrical, mechanical, and biological systems.
CLO4	Compare the performance of fractional order control algorithms with their integer-order counterparts for industrial applications.
CLO5	Apply the fractional order control algorithm for a given application through the case study/mini project.

Fractional order calculus: Review of basic definitions of integer-order (IO) derivatives and integrals and their geometric and physical interpretations, Definition of Riemann-Liouville (RL) integration, Definitions of RL, Caputo and Grunwald-Letnikov (GL) fractional derivatives (FDs), Various geometrical and physical interpretations of these FDs, Computation of these FDs for some basic functions like constant, ramp, exponential, sine, cosine, etc., Laplace transforms of FDs. Fractional-order modeling : Review of basic concepts of complex analysis, Concepts of multivalued functions, branch points, branch cuts, Riemann surface and sheets, Fractionalorder transfer function (FOTF) representation, Concepts like commensurate and noncommensurate TFs. fractional-order (FO) modelling of electrical circuit elements like inductor, capacitor, electrical. Models of basic circuits and mechanical systems using FO elements, FO models of heat transfer, A brief overview of FO models of biological systems. Fractional-order Control: Detailed discussion and analysis of the superiority of FO control over the conventional IO control in terms of closed-loop performance, robustness, stability, etc., FO PID control, design of FO state-feedback, Realization and implementation issues for FO controllers, survey of various realization methods and the comparative study, Case study.

Self-study:

Risk management in the industrial control system.

References:

1. K. B. Oldham and J. Spanier. *The Fractional Calculus* . Dover Publications, USA, 2006.
2. Kilbas, H. M. Srivastava, and J. J. Trujillo. *Theory and Applications of Fractional Differential Equations*, Elsevier, Netherlands, 2006.
3. Podlubny. *Fractional Differential Equations*. Academic Press, USA, 1999.
4. C. A. Monje, Y. Q. Chen, B. M. Vinagre, D. Xue, and V. Feliu. *Fractional-order Systems and Control: Fundamentals and Applications.* Springer-Verlag London Limited, UK, 2010.
5. R. L. Magin. *Fractional Calculus in Bioengineering*. Begell House Publishers, USA, 2006.
6. R. Caponetto, G. Dongola, L. Fortuna, and I. Petras. *Fractional Order Systems: Modeling and Control Applications*. World Scientific, Singapore, 2010.
7. K. S. Miller and B. Ross. *An Introduction to the Fractional Calculus and Fractional Differential Equations*. John Wiley & Sons, USA, 1993.
8. S. Das. *Functional Fractional Calculus for System Identification and Controls*, Springer, Germany, 2011.
9. M. D. Ortigueira. *Fractional Calculus for Scientists and Engineers. Springer*, Germany, 2011.
10. Petras. *Fractional-Order Nonlinear Systems: Modeling, Analysis and Simulation*. Springer, USA, 2011.

MTE ****: HUMAN ROBOT INTERACTION [3 0 0 3]

At the end of the course the students will be able to:

CLO1	Apply the human computer interactions for physical task executions
CLO2	Examine the design and software methodologies for human robot interaction
CLO3	Illustrate Mobile Ecosystem and Mobile Design along with Models and Theories for HRI
CLO4	Relate the web interface design processes tools

IO channels, Framework and design flow, Ergonomics, prototyping and lifecycle, usability engineering, HCI models, Cognitive and scoio organizational issues, Evalution techniques and .design rules. Collaborative models – HCI, application framework, mobile HCI design and case study, virtual layouts and process flow in web interfacing design.

Self-Study:

Case studies on different human robot interactions.

References:

1. Alan Dix, Janet Finlay, Gregory Abowd, Russell Beale, *Human Computer Interaction*, (3e), Pearson Education, 2004.
2. Brian Fling, *Mobile Design and Development*, (1e), O'Reilly Media Inc., 2009.
3. Bill Scott and Theresa Neil, *Designing Web Interfaces*, (1e), O'Reilly, 2009.

MTE ****: MACHINE LEARNING [3 0 0 3]

At the end of the course the students will be able to:

CLO1	Recognize the underlying principles of Machine Learning, associated algorithms and their applications.
CLO2	Describe various algorithms of supervised and unsupervised learning for different applications.
CLO3	Apply the supervised and unsupervised learning algorithms to analyse data and perform predictions.
CLO4	Comprehend the Neural Networks, apply to a real life problem, optimize the models and perform analysis on results obtained.

Introduction to Machine Learning, Review of Linear Algebra, Review of Probability theory, Overview of Convex optimization, Hidden Markov models, Bayesian decision theory, Maximum likelihood ratio, Parametric classification, Regression, Multivariate methods, K-nearest neighbor classification, Supervised learning: Logistic regression, Perceptron, Generative learning algorithms, Naïve Bayes, Support vector machines, Model selection and feature selection, Evaluation and debugging learning algorithms. Unsupervised learning: Clustering, K-means, Hierarchical clustering, Competitive learning, Dimensionality reduction techniques, Hidden Markov model, Linear Regression, Generating diverse learners, Ensemble techniques. Applications of Machine Learning in diverse fields

References:

1. Shai Shalev-Shwartz and Shai Ben-David, *Understanding Machine Learning*, Cambridge University Press. 2017.
2. Ethem Alpaydin, *Introduction to Machine Learning*, (2e), MIT Press, 2010.
3. Mehryar Mohri, Afshin Rostamizadeh and Amet Talwalkar, *Foundation of Machine Learning*, (1e), MIT Press 2012.
4. Dive into Deep Learning Aston Zhang and Zachary C. Lipton and Mu Li and Alexander J. Smola, 2019
5. Christopher M. Bishop, *Pattern Recognition and Machine Learning*, (1e), Springer, 2007.

MTE ****: MACHINE TOOL TECHNOLOGY [3 0 0 3]

At the end of the course the students will be able to:

CLO1	Comprehend the Fundamentals, Basic Processes, and various common aspects of metal cutting.
CLO2	Identify the suitable tools for various machining operations based on materials, tool wear, tool life, and other tooling systems
CLO3	Design different jigs and fixtures based on their location, principles and types.
CLO4	Demonstrate knowledge and understanding of work ethical aspects and technological risks in industries.
CLO5	Inculcate ethical principles in teamwork, as well as industrial practises that are compatible with Digital Manufacturing.

Types of motion in cutting, cutting speed, feed, depths of cut in machining, cutting tools classification, nomenclature of single point cutting tool, difference between orthogonal and oblique cutting, mechanism of metal cutting, types of chips, chip breakers, forces acting on a tool, merchant circle diagram, velocity relations, specific energy in cutting, tool wear, tool life factors, Taylor's tool life equation, tool wear mechanisms, heat distribution in metal cutting, measurement of temperature in metal cutting, lathe tool dynamometer, cutting fluids selection and applications, cutting tool materials, specifications for inserts and tool holders. CNC tooling, tool presetting, automated tool & pallet changing, work holding, cutting process parameter selection, jigs and fixtures, types of clamping devices, principles of clamping. Self-Study – Industrial ethics and technological risks.

References:

1. Milton C.Shaw, *Metal Cutting Principles, (2e)*, Oxford University Press, 2000.
2. Kempster, *Jigs and Fixtures, (3e)*, Mark Howard Publications, 2004.
3. Steve Krar, Arthur Gill and Peter Smid, *Machine Tool Technology Basics, (2e),* Industrial Press Inc., U.S, 2012.
4. Sharma. P. C, *A Text Book of Production Engineering, (7e)*, SChand Publishers, New Delhi, 2008.

MTE **: MACHINE VISION [3 0 0 3]**

At the end of the course the students will be able to:

CLO 1	Apply the need for image processing and intelligent vision systems in a wide range of industrial and research applications.
CLO 2	Implement the feature extraction algorithms to compare with the conventional methods using software tools.
CLO 3	Select appropriate algorithm and experimental tools to provide innovative solutions for video-based applications.

CLO 4	Design 3D vision algorithm for robotic applications with critical evaluation of methods involved with limitations.
CLO 5	Analyse various vision algorithms in the form of technical report for robotics and industry automation applications.

Vision System Components, Pinhole Camera Model, Image Acquisition, Sampling & Quantization, Fundamentals of Color Image Processing and Color Space Conversion, Basic Operations on Images, Geometrical Transformations, Image Enhancement, Spatial Domain, and Frequency Domain Processing, Image Noise, Image Restoration, Morphological Operations, Region Segmentation, Feature Extraction, Background Subtraction, Lucas Kanade Optical Flow Estimation, Object Tracking using Kalman Filter, Localization using Passive Markers. Linear Camera Model, RGB+D camera, Time of Flight (ToF) cameras, Camera Calibration, Intrinsic and Extrinsic Camera Parameters, Stereo, Epipolar Geometry, Estimation of Fundamental Matrix, Computing Depth, Motion Field and Optical Flow, Structure from Motion, Observation Matrix, Computer Vision Software Tools for Color and Shape Detection, Human Detection, Object Tracking, Camera Calibration, Depth Estimation, Stereo Correspondence Algorithms.

References:

1. Rafael C. Gonzalez, Richard E. Woods, *Digital Image Processing*, (3e), Pearson Education, 2008.
2. Szeliski, *Computer Vision: Algorithms and Applications*, Springer, 2012
3. Milan Sonka, Vaclav Hlavac, Roger Boyle, *Image Processing, Analysis and Machine Vision*, (2e), 1998.
4. Boguslaw Cyganek & J. Paul Siebert, *An Introduction to 3D Computer Vision Techniques and Algorithms*, (1e), Wiley, 2009
5. David A. Forsyth, Jean Ponce, *Computer vision: A modern approach*, Pearson Education Limited.
6. E.R. Davies, Royal Holloway, *Machine Vision: Theory, Algorithms and Practicalities*, (3e), University of London, 2004.

MTE ****: MECHANICAL VIBRATIONS [3 0 0 3]

At the end of the course the students will be able to:

CLO1	Explain basics of sound, noise and vibration; as well as their control strategies.
CLO2	Derive equations of motion for undamped one-dimensional vibrations and solve problems of damped free vibrations.
CLO3	Analyse and solve problems of forced vibrations involving frequency response curves, phase angle plots, vibration isolation and transmissibility.
CLO4	Analyse and solve problems involving vibrations of systems having more than one degree of freedom.
CLO5	Recall and explain concepts involving vibrations of continuous systems.

Introduction to mechanical vibration, vibration system and types, vibration analysis - degrees of freedom, mathematical modelling, equations of motion, SHM, natural frequency of single degree of freedom system – mathematical modelling, derivation of governing differential equation of motion for free undamped and damped systems, forced vibration – single degree of freedom system under harmonic excitation, steady state, reciprocating and rotating unbalance, transmissibility and isolation, base excitation with harmonic input. Two degree of freedom systems - natural frequencies and mode shapes, forced vibration. Natural frequency of multi-degree of freedom systems, vibration control, vibration testing and measurement.

Self-study:

Case studies on vibrational experiments using different examples

References:

1. Groover G.K., *Mechanical Vibrations,* Nemchand and Bros, Roorkee, 2012.
2. Singirisu Rao S, *Mechanical Vibration,* Pearson Education, Delhi, 2004.
3. Dukkapatti Rao V., *Text Book of Mechanical Vibration*. Prentice Hall of India Ltd, 2004.
4. Daniel Imnan J. *Engineering Vibration,* Prentice Hall, New Delhi, 2001.
5. Thomson W.T., *Theory of Vibrations with Applications,* Chapman and Hall, 4th Edition, 1993.

MTE **: MICRO AND NANO FABRICATION OF ELECTRONIC DEVICES [3 0 0 3]**

At the end of the course the students will be able to:

CLO1	Understand the principles of intrinsic and extrinsic semiconductors and their behavior with regards to conductivity, fermi level, and bandgap.
CLO2	Identify the characteristics of common electronic devices, such as pn junction diodes, Zener diodes, Schottky diodes, BJTs, MOSFETs, LEDs, photodetectors, and solar cells.
CLO3	Apply the concepts of semiconductor manufacturing, including the clean room concept, crystal structure of silicon, material properties, silicon wafer types, and basic wafer fabrication operations.
CLO4	Analyze the fabrication processes involved in semiconductor device manufacturing, such as lithography, etching, deposition, growth, metallization, and polishing, and understand how they are used to create ICs.
CLO5	Analyze various techniques used for device characterization, such as two-point and four-point probes, capacitance voltage profiling, SEM, TEM, and X-ray diffraction, and their importance in the evaluation of the fabrication process and device quality.
CLO6	Compare the various packaging methods used for electronic devices and their impact on device performance and reliability

Intrinsic and extrinsic semiconductors, Zener diodes, Schottky diode, BJTs, MOSFETs, optoelectronic devices- LEDs, photodetectors, solar cells. Moore’s Law, Scaling in CMOS, clean room concept, crystal structure of silicon, material properties, silicon wafer types, basic wafer fabrication operations: layering, patterning, doping, heat treatment. Lithography-photolithography, X-ray lithography, e-beam lithography, scanning probe, photoresists, masks; Etching- wet and dry; Deposition and growth- CVD, PVD, ALD, MBE; metallization-sputtering, CVD, electroplating; Polishing. Process and device evaluation, process yield; CMOS and SOI Technology, SOI MOSFET, strained SiGe MOSFET, Characterization: two-point, four-point probes, capacitance voltage profiling, scanning electron microscopy, transmission electron microscopy, X-ray diffraction; Packaging methods.

References:

1. Stephen A. Campbell, *Fabrication Engineering at the Micro- and Nanoscale*, Oxford University Press, 2013
2. Gary S. May, Simon M. Sze, *Fundamentals of semiconductor fabrication*, Wiley, 2003.
3. James D. Plummer, Michael D. Deal, Peter B. Griffin, *Silicon VLSI Technology: Fundamentals, Practice and Modeling*, Prentice Hall, 2009
4. D. Chattyopadhyay, P.C. Rakshit, *Electronics Fundamentals and Applications*, New Age International, 2020

MTE ****: MICRO ELECTRO MECHANICAL SYSTEMS [3 0 0 3]

At the end of the course the students will be able to:

CLO1	Explain MEMS Technology, Present, Future and Challenges.
CLO2	Illustrate micro sensors, micro-actuators, their type, and applications..
CLO3	Analyse the design concept, scaling law and material for MEMS
CLO4	Explain the fabrication technique and packing system

MEMS and Microsystems applications, Review of Mechanical concepts, Actuation and Sensing techniques, Scaling laws in miniaturization, Materials for MEMS, Micro System fabrication techniques, Micro manufacturing, Micro system Packaging, Bonding techniques for MEMS, Overview of MEMS areas.

References:

1. Chang Liu, Foundations of MEMS, Pearson 2012
2. Tai-Ran Hsu, MEMS and Microsystems Design and Manufacture, TMH, 2002
3. Chang C Y and Sze S. M., VLSI Technology, McGraw-Hill, New York, 2000
4. Julian W Gardner, Microsensors: Principles and Applications, John Wiley & Sons, 1994
5. Mark Madou, Fundamentals of Micro fabrication, CRC Press, New York, 1997
6. Stephen D. Senturia, Microsystem design, Springer (India), 2006.
7. Thomas B. Jones, Electromechanics and MEMS, Cambridge University Press, 2001
8. James J Allen, MEMS Design, Taylor and Francis, 2005.

MTE ****: MICRO MANUFACTURING SYSTEMS [3 0 0 3]

At the end of the course, students will be able to:

CLO1	Analyze various types of traditional and advanced micromachining systems.
CLO2	Appreciate the types of microcasting, micromolding and microforming.
CLO3	Classify the type of microcasting, micromolding, microforming and nanofinishing.
CLO4	Appreciate the case studies of emerging research in micro manufacturing systems.

Introduction, working principles and process parameters, machine tools, applications of the micro manufacturing processes, challenges in meso, micro, and nanomanufacturing, industrial applications and future scope of micro-manufacturing processes. Different instruments related to micro manufacturing such as microsensors, microactuators, microsystems. Working principles, machine construction, and applications of micromachining, nanofinishing, microjoining, microforming, microcasting, micromolding, LIGA for micro/nano products and features, the diversified industrial applications of the micro-manufactured processes, and recent research trends in this area.

References:

1. Jain V. K., *Introduction to Micromachining,* Narosa Publishing house Pvt. Ltd., 2010.
2. Jain V. K., *Micromanufacturing,* CRC Press, 2012.
3. Jain V. K., *Advanced Machining Processes,* Allied Publishers Pvt. Ltd., 2014.
4. Mahalik N. P., *Micromanufacturing & Nanotechnology,* Springer Berlin Heidelberg, 2006.
5. Jackson J. M., *Microfacbrication & Nanomanufacturing*, CRC Press, 2005.

MTE ****: NANO TECHNOLOGY [3 0 0 3]

At the end of the course, students will be able to:

CLO1	Analyze the physical chemistry of nanosystems.
CLO2	Appreciate the concepts of microscale and nanoscale heat conduction principles.
CLO3	Classify the types of microactuators.
CLO4	Appreciate the case studies of emerging research in nanotechnology.

Introduction to nanotechnology, bottom-up and top-down approaches, physical and chemical properties, methods of preparation of nanoparticles, carbon nanostructures and their applications, physical chemistry of nanosystems, micro electro mechanical devices and technologies - microsensors, MEMS fabrication processes and applications, microscale and nanoscale heat conduction, nanofluids preparation and characterization, nanomaterials used in energy and environmental applications and their properties, future development of micro actuators, nanolithograghy, photoresist patterning, photolithography, electron beam lithography, production of polygon mirrors, optic fibers, future trends in nanotechnology.

References:

1. Charles P. Poole, *Introduction to Nanotechnology*, Wiley-Interscience, 2003.
2. Guozhong Cao, *Nanostructures & Nanomaterials*, Imperial College Press, 2004. 532
3. C B Sobhan, *Microscale and Nanoscale Heat Transfer*, Taylor and Francis, 2008.
4. Norio Taniguchi, *Nanotechnology*, Oxford University Press, 2008.
5. James J Allen, *MEMS Design*, Taylor and Francis, 2005.

MTE ****: OBJECT ORIENTED PROGRAMMING USING PYTHON [3 0 0 3]

At the end of the course the students will be able to:

CLO1	Illustrate the fundamentals of object oriented programming.
CLO2	Deduce the different concepts of classes and objects along with data structures in Python programming.
CLO3	Deduce the concepts of Exception and File handling using Python.
CLO4	Develop data classification and mining algorithms for data pertaining to industrial automation using Python.
CLO5	Develop machine learning algorithms for data pertaining to industrial automation using Python.

Introduction to the Object-oriented programming using Python language, Data types, Variable and arrays, Type conversion and casting, Generators, Iterators, Operators, control statements, functions and Modules. Classes and inheritance, Abstraction, Encapsulation, Polymorphism, Packages and interfaces, Working with In-built data-structures, List, Tuples, Dictionaries and set and application involving abstract DS. Exception handling, Thread concepts – synchronization, inter thread communication, Input/output – File: file input stream, File output stream, Random access files, Reader, Writer, Decorators, Map, Reduce and Collections. Serialization, Serializable, Object input stream, Object output stream, Swings - swing fundamentals, Introduction to event handling. Application: GUI, Accessing a database, Django, Flask.

References:

1. John Zelle. *Python Programming: An Introduction to Computer Science* (3e). CRC Press.
2. Muller and Guido. *Introduction to Machine Learning with Python: A Guide for Data Scientists*. (2e). Prentice Hall of India.
3. Mark Lutz. *Programming Python: Powerful Object-Oriented Programming.* (2e). Prentice Hall of India.

Self-Study:

Courseera course entitled Python Programming for All.

MTE **: PRODUCTION AND OPERATIONS MANAGEMENT [3 0 0 3]**

At the end of the course the students will be able to:

CO1	Apply appropriate qualitative and quantitative forecasting techniques for different type of production activities & their functions.
CO2	Apply suitable methods to optimize resources required during capacity and aggregate planning.
CO3	Solve job scheduling and inventory management problems using appropriate techniques.
CO4	Formulate suitable material requirement plans and precedence diagrams in balancing production lines.
CO5	Develop suitable plan for plant location and floor layout selection leads to optimal use of resources.
CO6	Inculcate ethical principles in teamwork, as well as industrial practises that are compatible with production and operations management.

Introduction, production consumption cycle, forecasting- quantitative and qualitative methods, Forecast control, measures of forecast accuracy product development and design, product life cycle, process design, process charts, flow diagrams and man machine charts capacity planning, breakeven analysis, single and multi-product P-V charts, aggregate planning, trial and error approach, use of transportation algorithm, job shop scheduling, Sequencing of "n" jobs through 2 machines, "n" jobs through 3 machines and 2 jobs through "n" machines inventory management and line balancing, resource conversion and concepts, planning models and behavioural applications, case studies.

Self-study:

Coursera course - Ethics, technology and engineering.

References:

1. Adam Everett E. Jr. and Ebert Ronald J., *Production and Operations Management*, Prentice Hall of India Pvt. Ltd., 2002.
2. Chase Richard B., Aquilano Nicholas J. and Jacobs F. Roberts, *Production and Operations Management*, Tata McGraw-Hill publishing Co. Ltd., 1999.
3. Eilon Samuel, *Elements of Production Planning and Control,* Universal Publishing Corporation, 1991.
4. Monks Joseph G., *Operations Management*, Tata McGraw-Hill Publishing Co. Ltd., 2004.
5. Krajewski Lee J. and Ritzman Larry P., *Operations Management*, Pearson Education Pvt. Ltd., 2005.
6. https://www.coursera.org/learn/ethics-technology-engineering

MTE ****: REINFORCEMENT LEARNING FOR ROBOTICS [3 0 0 3]

At the end of the course the students will be able to:

CLO 1	Construct a Reinforcement Learning system that knows how to make automated decisions.
CLO 2	Relate Reinforcement Learning to fit under the span of machine learning, deep learning, supervised and unsupervised learning.
CLO 3	Illustrate the space of RL algorithms such as Temporal- Difference learning, Monte Carlo, Sarsa, Q-learning, Policy Gradient, Dyna, etc.,.
CLO 4	Formalize tasks as a Reinforcement Learning problem in implementing a solution.
hCLO 5	Modelling optimal policies for different tasks

Probability basic concepts: Probability, Random variables discrete and continuous, Conditional probability, Probability distributions, Bayes theorem, Maximum Likelihood and MAP. Sequential Decision Making with Evaluative Feedback. Learning Action Values, Estimating Action Values Incrementally, Optimistic Initial Values Upper-Confidence Bound (UCB) Action Selection, Jonathan Langford: Contextual Bandits for Real World Reinforcement Learning. Markov Decision Processes. Examples of MDPs, The Goal of Reinforcement Learning, Michael Littman: The Reward Hypothesis. Continuing Tasks, Examples of Episodic and Continuing Tasks. Value Functions & Bellman Equations: Value Functions, Rich Sutton and Andy Barto: A brief History of RL, Bellman Equation Derivation Why Bellman Equations? Optimal Policies, Optimal Value Functions, Using Optimal Value Functions to Get Optimal Policies. Dynamic Programming: Iterative Policy Evaluation, Policy Improvement, Policy Iteration, Flexibility of the Policy Iteration Framework, Efficiency of Dynamic Programming. Monte Carlo Methods for Prediction & Control: Using Monte Carlo for Prediction, Using Monte Carlo for Action Values, Using Monte Carlo methods for generalized policy iteration, Solving the Blackjack, Example: Epsilon-soft policies off-policy learning matter, Importance Sampling, Off-Policy Monte Carlo Prediction. Temporal Difference Learning Methods for Prediction: Rich Sutton: The Importance of TD Learning, The advantages of temporal difference learning Comparing TD and Monte Carlo, Andy Barto and Rich Sutton: More on the History of RL. Temporal Difference Learning Methods for Control: Sarsa: GPI with TD, Sarsa in the Windy Grid World, What is Q-learning?, Q-learning in the Windy Grid World, How is Q-learning off-policy?, Expected Sarsa, Expected Sarsa in the Cliff World, Generality of Expected Sarsa. Planning, Learning & Acting: What is a Model, Comparing Sample and Distribution Models, Random Tabular Q-planning, The Dyna Architecture, The Dyna Algorithm, Dyna & Q-learning in a Simple Maze, what if the model is inaccurate? In-depth with changing environments, Drew Bagnell: self-driving, robotics, and Model Based RL.

Self-study:
Case studies on applications and implementation of different reinforcement learning algorithms

References:

1. Richard S. Sutton and Andrew G. Barto. *Introduction to Reinforcement Learning*, (2e), MIT Press. 2017. [Draft copies available now]
2. Dimitri Bertsikas and John G. Tsitsiklis. *Neuro Dynamic Programming*. Athena Scientific. 1996.
3. Enes Bilgin, *Mastering Reinforcement Learning with Python: Build next-generation, self-learning models using reinforcement learning techniques and best practices.* Packt, (2e). 2020..

MTE ****: RENEWABLE ENERGY TECHNOLOGY [3 0 0 3]

At the end of the course the students will be able to:

CLO1	Analyse the influence of renewable energy sources on environment.
CLO2	Identify the significance and applications of Solar energy and their utilizations.
CLO3	Illustrate the governing and types of wind energy conversion systems.
CLO4	Examine various alternative energy sources such as Tidal,Geo thermal, Biomass and Hydrogen Fuel Cells.

Energy resources – Electrical energy generation. Indian Power Generation. Environmental aspects of Electrical Energy generation. Solar Energy – fundamentals of solar energy, Solar thermal and Photovoltaics. Solar cells, solar modules and sizing, solar photovoltaics systems, solar photovoltaic applications. Grid connected PV systems. Wind Energy Systems – Fundamentals of wind energy systems. Grid connected and standalone wind power generation. Small hydropower, Geo-thermal power generation. Tidal energy, wave energy and conversion systems. Biomass Energy. Fuel cells and Hydrogen Energy Systems.

Self-study:

1. High efficient solar panels with multi crystalline.
2. New wind turbines: Bladeless turbines

References:

1. D.P. Kothari, K.C. Singal, and Rakesh Ranjan, *Renewable Energy Sources and Emerging Technologies*, (3e), PHI, 2022.
2. G.D. Rai, *Non-conventional Energy Sources*, Khanna Publishers, 2004.
3. Solanki C.S, *Solar Photovoltaics - Fundamentals, Technologies and Applications*, (3e), PHI, 2015.
4. S.M. Muyeen, *Wind Energy Conversion Systems: Technology and Trends (Green Energy and Technology)*, Springer, 2012.

MTE **** SUSTAINABLE MANUFACTURING [3 0 0 3]

At the end of the course the students will be able to:

CLO1	Comprehend the dimensions of sustainability such as economy, environment and technology, and quality concerns.
CLO2	Assess sustainability of various manufacturing processes based on various concept models of sustainable engineering.
CLO3	Evaluation on Machining Processes for Sustainable Manufacturing and incorporating suitable alternatives.
CLO4	Demonstrate knowledge and understanding of environmental aspects and technological risks in industries.
CLO5	Inculcate ethical principles in teamwork, as well as industrial practises that are compatible with sustainable Manufacturing.

Concept of sustainability, environmental, economic and social dimensions of sustainability. Relation between green, lean and sustainable manufacturing. Environmental conscious- quality function deployment, Environmental impact assessment methods, Sustainability assessment-concept models and various approaches, Sustainable manufacturing processes - Abrasive Jet Machining, Laser beam machining, Ultrasonic Machining, Electro Chemical Machining, Electro Discharge Machining. Product Life cycle management and analysis - Tools for LCA, optimization for achieving sustainability in manufacturing, value analysis, analysis for carbon footprint-software packages for sustainability analysis. Case studies on Evaluation on Machining Processes for Sustainable Manufacturing, SDL on Introduction to Sustainability using coursera course.

References:

1. Subramanian S. M., Monica M.S., *Handbook of Sustainability in Additive Manufacturing*, Vol. 2, Springer Publication, 2018.
2. Atkinson G, Dietz S, Neumayer E, *Handbook of sustainable manufacturing*, Edward Elgar Publishing limited, Ed. 2, 2014.
3. Paul C. P., Jinoop A. N., *Additive Manufacturing*, McGraw Hill,2021.
4. https://www.coursera.org/learn/sustainability

MTE **: SYSTEMS MODELLING AND SIMULATION [3 0 0 3]**

At the end of the course, students will be able to:

CLO1	Analyze the principles of modelling physical systems.
CLO2	Appreciate the concepts of various modeling methods.
CLO3	Classify the algorithms used for system identification.
CLO4	Appreciate the case studies of emerging research in systems modelling and simulation.

Principles of modeling and simulation, modeling and simulation of mixed systems, transfer function, block diagram, state space representation of SISO, MIMO, modeling of dynamic systems, construction, analysis, practical applications, linear systems, methods of model order determination, impulse and frequency response methods, system identification, algorithms for parameter estimation, gradient algorithm, least square algorithm, ARX, ARMAX applications of LS and ARMA methods, regression methods, introduction to nonlinear modeling, identification NARMAX model, case studies UAV quad-rotor, hard discs, maglev systems, ball and beam systems.

References:

1. George Pelz, *Mechatronic Systems Modeling and Simulation with HDLs*, Wiley, 2003.
2. Devdas Shetty, Richard Kolk, *Mechatronics System Design*, *(2e)*, Cengage Learning, 2010.
3. Benjamin C. Kuo, Farid Golnarghi, *Automatic Control Systems*, *(8e)*, Wiley, 2009.
4. Jack W. Lewis, *Modeling of Engineering Systems PC-Based Techniques and Design Tools*, High Text Publications, 2000.
5. Ioan D. Landau, Gianluca Zito, *Digital Control Systems Design, Identification and Implementation*, Springer, 2006.
6. System Identification: Theory for the User (2nd Edition), Lennart Ljung, Pearson: Prentice Hall.

MTE **: WIRELESS SENSOR NETWORKS [3 0 0 3]**

At the end of the course, students will be able to:

CLO1	Develop an energy efficient single node architecture for wireless sensor networks.
CLO2	Classify the design issues and different categories of MAC protocols.
CLO3	Compare among various routing protocols to facilitate the exchange of routing information between routers.
CLO4	Analyse the sensor network platform and tools state-centric programming.
CLO5	Implement wireless sensor networks in various applications through case study.

Challenges for wireless sensor networks, Single node architecture – Hardware components, Energy consumption of sensor nodes, Network architecture – Types of sources and sinks, Single hop versus multi-hop networks, Multiple sinks and sources, Wireless channel and communication fundamentals – Frequency allocation, Modulation and demodulation, MAC protocols – Fundamentals of (wireless) MAC protocols, contention-based protocols, SMAC – BMAC, TRAMA, IEEE 802.15.4 MAC protocol, Q-MAC (Querry MAC), Q-MAC (QoS MAC). Routing challenges and design, SPIN COUGAR, ACQUIRE, LEACH, PEGASIS, GF, GAF, GEAR, Aggregation techniques – TAG, Tiny DB traditional transport control protocols. Wireless protocols – LANs: 802.11, 802.11a/b/g, 802.16-WiMAX, UWB communications, wireless personal area networks, Blue Tooth. Healthcare monitoring system using wireless sensor networks, remote home lighting and appliance control system, automatic speed control and vehicle tracking using GSM and GPS technologies.

References:

1. Kazem Sohraby, Daniel Minoli and Taieb Znati, *Wireless Sensor Networks Technology-*

Protocols and Applications, John Wiley & Sons, 2010.
2. Holger Karl and Andreas Willig, *Protocols and Architectures for Wireless Sensor Networks,* John Wiley & Sons, Ltd Paperback edition, 2007.
3. Ananthram Swami, Qing Zhao, Yao-Win Hong, Lang Tong Pub, *Wireless Sensor Networks Signal Processing and Communications*, First Edition, John Wiley & Sons, 2007.
4. Murthy, *Ad Hoc Wireless Networks: Architectures and Protocols,* Pearson Education, 2006.
5. Sridhar S. Iyengar, NandanParameshwaran, Vir V. Phoha, N. Balakrishnan, Chuka D. Okoye, *Fundamentals of Sensor Network Programming: Applications and Technology*, First Edition, John Wiley & Sons, 2010.

OPEN ELECTIVES

MTE ****: AUTONOMOUS MOBILE ROBOTS [3 0 0 3]

At the end of the course the students will be able to:

CLO1	Apply various design choices for a robotics system
CLO2	Implement the right methods to control a mobile robot for a particular task.
CLO3	Integrate appropriate methods for sensing, cognition and actuation
CLO4	Implement perception, localization/navigation and control methods on a mobile robot
CLO5	Construct a planning roadmap and apply search techniques to compute a dynamically feasible, collision-free path between two locations.

Locomotion: Introduction, Legged Mobile Robots, Wheeled Mobile Robots. Mobile Robot Kinematics and Motion in Global Coordinates: Kinematic Models and Constraints, Mobile Robot Maneuverability, Mobile Robot Workspace, Dynamics of Quadrotor-Type Mobile Robots. Perception: Sensors for Mobile Robots, Feature Extraction. GNSS and Mobile Robot Localization: The Challenge of Localization: Localization-Based Navigation versus Programmed Solutions, Map Representation. Probabilistic Map-Based Localization. Global Navigation Satellite System. Planning, Navigation and Energy Considerations: Competences for Navigation, Navigation Architectures, Energy Limitations and Energetic Efficiency of Mobile Robots.

References:

1. Siegwart, Roland, Illah Reza Nourbakhsh, and Davide Scaramuzza. *Introduction to autonomous mobile robots*. MIT press, 2011.
2. Howie Choset, Kevin M Lynch, *Principles of Robot Motion*, MIT Press, 2005.
3. King Sun Fu, Gonzalez , *Robotics- control, sensing, vision, and intelligence,* McGraw-Hill, 1987.
4. Kagan, Eugene, Nir Shvalb, and Irad Ben-Gal, eds. *Autonomous mobile robots and multi-robot systems: Motion-planning, communication, and swarming*. John Wiley & Sons, 2019.

MTE ****: FARM AUTOMATION [3 0 0 3]

At the end of the course the students will be able to:

CLO1	Analyze and evaluate the benefits and drawbacks of various farm automation systems and agriculture robotic vehicles for increased efficiency and productivity in agriculture.
CLO2	Design and develop automated irrigation systems using IoT and machine learning technologies for optimal crop growth and water conservation.
CLO3	Create and implement automation strategies for protected cultivation, including seed processing, mechanical harvesting, and pruning.
CLO4	Synthesize and apply knowledge of robotics in agriculture to automate tasks such as harvesting, weed control, and nutrient analysis.
CLO5	Critically evaluate and design food processing systems using novel techniques, including material handling, packaging, and transportation, to meet safety and quality standards.

Farm automation system, sensors, controller, actuators, regulators and servos; Agriculture robotic vehicles: Wheel-type robot tractor, Crawler type robotic tractor, rice transplanting robot, robot combined harvester; Automation in irrigation: Automated Irrigation, Portable timer system, Timer/Sensor Hybrid/SCADA, Methods of automating Irrigation layout, Machine Learning in Tank Monitoring System. IoT in Irrigation: IoT based Automated Irrigation System, Solar based Automatic Irrigation System, components, operation, Automation by sensing soil moisture, Automation using ANN based controller operation, Crop water estimate, Remote Monitoring design of Automatic Irrigation system, Cost and Benefits of Automation; Automation in Protected Cultivation: Automation in seed, seedling and nursery, automation in seed processing, automation in polyhouse: Heading and Pruning Automation in Polyhouse Production, Mechanical Mass Harvesting of Fruits, Nuts and Vegetables; Automation through robots: Harvesting and picking, weed control, Autonomous mowing, pruning, seeding, spraying and thinning, Phenotyping, Sorting and packing, Utility platforms robots, Soil moisture, nutrient status analysis by robots, Smart cameras for weed-crop segmentation; Automation in food processing: Introduction, Post-Harvest and Food Processing Unit Operations, Material Handling, Packaging and Transportation, Novel Food processing techniques.

References:

1. Brian Wahlin and DarellZimbelman, *Canal Automation for Irrigation Systems*, American Society of Civil Engineers, 2014
2. Qin Zhang and Francis J Pierce, *Agricultural Automation: Fundamentals and Practices*, CRC Press
3. Darwin G. Caldwell, *Robotics and Automation in the Food Industry. Current and Future Technologies*, Woodhead Publishing Series in Food Science, Technology and Nutrition, (2013).
4. P.J. Fellows, *Food Processing Technology, Principles and Practice*, (4e).

MTE **: HYDRAULICS AND PNEUMATICS SYTEMS [3 0 0 3]**

At the end of the course the students will be able to:

CLO1	Discuss the fundamental concepts of fluid power recognize the various types of fluid flow problems encountered in practice.

CLO2	Explain the working, utilization, standard notations of various power generating and distributing elements for a hydraulic and pneumatics systems.
CLO3	Solve job scheduling and inventory management problems using appropriate techniques.
CLO4	Describe the operating principle of various actuators, valves of hydraulics and pneumatics systems.
CLO5	Outline the concepts of Electro – pneumatic system, sensors and their application in various automation systems.

Pneumatic systems, structure and signal flow, compressors, actuators and control valves, single acting and double acting cylinders, manual pneumatics, single and multiple actuators, limit switches, proximity sensors, electro pneumatics and design of electro pneumatic circuits, direction control valves, relay control systems, timers, counters, pressure control valves, closed loop pneumatics and Flow control valves. Hydraulic systems, physical principles of oil hydraulics, hydraulic actuators, valves and accessories, hydraulic power pack, types of hydraulic pumps, accumulator, Filters, hydraulic circuits, regenerative, meter in, meter out, bleed off, sequencing, pressure reducing circuits, electro hydraulic circuits, proportional hydraulics and servo hydraulics.

References:

1. Anthony Esposito, *Fluid power with applications*, Pearson Education, 2003.
2. Andrew A. Parr, *Hydraulics and Pneumatics*, Elsevier Science & Technology Books, 1999.
3. Scholz D., *Proportional Hydraulics*, Festo Didactic GMBH & Co, Germany, 2002.
4. Majumdar S.R., *Pneumatic Systems - Principles and Maintenance*, Tata McGraw Hill, 2000.
   Merkle D., Rupp K. and Scholz D., *Electrohydraulics Basic Level TP 601*, Festo Didactic GMBH & Co, Germany, 1994.

MTE **: INDUSTRIAL IoT [3 0 0 3]**

At the end of the program the students will be able to:

CLO1	Analyze and evaluate the various sensors and actuations used in IIoT.
CLO2	Design and develop PLC programs for applications of IIoT.
CLO3	Classify various protocols used in communication of IIoT environments.
CLO4	Appreciate the concepts of database security and applications in IIoT environment.

Introduction to Industrial IoT, Components of IIoT. Sensors, Acceleration: Accelerometers (Piezoelectric, Capacitive); Proximity & Range: Proximity Switches, Ultrasonic Sensor, Hall Effect Sensor, Eddy Current Sensor, Temperature: Bimetallic, RTD, Thermocouple, Thermistor, Optical Pyrometer; Pressure: Electric Transducers, Pressure Transmitters, Pressure Gauges – McLeod, Knudsen, Pirani, Vacuum; Flow: Ultrasonic, V Cone, Laser Doppler, Mass flowmeters. Introduction to PLC: Advantage of PLC, and Chronological Evolution of a PLC, Type of PLC, Parts of PLC and Block diagram PLC, I/O modules and interfacing, networking of PLC ,Input-Output System Sinking and Sourcing, power supply module, Programming Equipments.

Programming formats using contacts and coils, latching etc. Converting simple relay logic diagram to PLC ladder diagram, Digital logic implementation in ladder programming, Timer and counter functions, Arithmetic functions, R-trig / F- trig pulses, shift registers, sequence functions, PID principles and functional block, position indicator with PID control. Industrial Process Automation, Networks and Protocols: AS-i, CAN, DeviceNet, Interbus, LON, Foundation Fieldbus, HART, PROFIBUS-PA, BACnet, ControlNet, IndustrialEthernet, Ethernet/IP, MODBUS, PROFIBUS-DP. Database-System Applications, Purpose of Database Systems, View of Data, Database Languages, Relational Databases. Introduction to security, Characteristics of Information, Components of an Information system, Security System Development Lifecycle, The Need for Security- Business Needs first, Threats, Attacks, Intruders, Intrusion detection.

References:

1. Liptak, B.G. (Ed.), *Instrument engineers' handbook, Vol. 3: Process software and digital networks*, (4e) CRC Press, Boca Raton, London, 2012.
2. Andrew S. Tanenbaum, *Computer Networks*, (5e), Prentice Hall of India Pvt. Ltd., 2011.
3. William Stallings, *Data and Computer Communications*, (8e), Prentice Hall of India Pvt. Ltd., 2014.

MTE ****: INTRODUCTION TO INDUSTRIAL ROBOTICS [3 0 0 3]

At the end of the course the students will be able to:

CLO1	Understand history, trends, advancements in industrial robotics and different associated factors and hence apply the fundamental understanding in selection of components of a robot.
CLO2	Analyze algebraic tools for the description of frame representation.
CLO3	Apply forward kinematics and inverse kinematics to compute position and joint variables respectively.
CLO4	Develop robot dynamic equations considering necessary forces for different configurations of robots.
CLO5	Develop programs for robotic arm with simulations for analyzing socio-economic and safety aspects of industrial robots.

Introduction: definition of robots, anatomy, degrees of freedom, Robot configuration, control parameters, actuators and sensors. Spatial Descriptions and Transformations: Frame representation and mapping, operators. Industrial Manipulator Kinematics: link description, orward kinematics of industrial robots, Inverse kinematics of standard industrial manipulators. Industrial Manipulator Dynamics: Jacobian and force vector. Forward dynamics and inverse dynamic simulations in Robo Analyzer software, Robotics Application: Image processing: colour detection through Open CV programming. Arduino programming for servo and DC motor control. Socio-economic and Safety Aspect of Industrial Robots: Social and labor issues impact. Economic analysis. Safety, training, maintenance and quality improvement, Robotics technology of the future.

References:

1. John J. Craig, *Introduction to Robotics: Mechanics and Control*, (3e), PHI, 2005.
2. C. Peter. *Robotics, Vision and Control: Fundamental Algorithms in MATLAB*. Vol. 73. Springer, 2011.
3. G. Ashitava, *Robotics: Fundamental Concepts and Analysis*, Oxford University Press, 2006.
4. Murray, Richard M., Zexiang Li, S. Shankar Sastry, and S. Shankara Sastry, *A Mathematical Introduction to Robotic Manipulation*, CRC press, 1994.
5. Siciliano, Bruno, and Oussama Khatib. "*Robotics and the Handbook*." Springer Handbook of Robotics. Springer, Cham, 2016.
6. Groover, Mikell P., Mitchell Weiss, and Roger N. Nagel. *Industrial robotics: technology, programming and application*. McGraw-Hill Higher Education, 1986.