

Department of Mechatronics
B. Tech. in Mechatronics 2022 Curriculum

Year	THIRD SEMESTER						FOURTH SEMESTER						
	Sub. Code	Subject Name	L	T	P	C	Sub. Code	Subject Name	L	T	P	C	
II	MAT 2121	Engineering Mathematics – III	2	1	0	3	MAT 2231	Engineering Mathematics – IV	2	1	0	3	
	MTE 2121	Data Structures and Algorithms	2	1	0	3	MTE 2221	Theory of Machines	2	1	0	3	
	MTE 2122	Digital Design and Verilog Programming	2	1	0	3	MTE 2222	Design of Machine Elements	3	1	0	4	
	MTE 2123	Digital and Analog CMOS Design	3	0	0	3	MTE 2223	Industrial Automation	3	0	0	3	
	MTE 2124	Mechanics of Robotics Systems	2	1	0	3	MTE 2224	Linear Control Theory	2	1	0	3	
	MTE 2125	Sensors and Transducers	3	0	0	3	MTE 2225	Microcontroller based System Design	2	1	0	3	
	MTE 2141	Industrial Robotics Lab	0	0	3	1	MTE 2241	CAD and Kinematics' Simulation Lab	0	0	3	1	
	MTE 2142	Integrated Electronics Lab	0	0	3	1	MTE 2242	Microcontroller Lab	0	0	3	1	
	MTE 2143	Manufacturing Processes Lab	0	0	3	1	MTE 2243	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				
III	FIFTH SEMESTER						SIXTH SEMESTER						
	HUM 3021	Engg. Economics and Financial Management	2	1	0	3	HUM 3022	Essentials of Management	2	1	0	3	
	MTE 3121	Digital Signal Processing	2	1	0	3	MTE 3221	Energy and Heat Transfer	3	0	0	3	
	MTE 3122	Electric Drives	3	1	0	4	FLEXICORE - 2	MTE 3222: Automobile Engineering/ ELE 3225- Automotive Mechanics for Electric Vehicles	3	0	0	3	
FLEXICORE - 1	MTE 3123: Manufacturing Technology/ ELE 3127: Foundations of EV and Hybrid Vehicles	2	1	0	3	MTE ****	Program Elective – I / Minor Specialization	3	0	0	3		

	MTE 3124	Hydraulics and Pneumatics Systems	3	0	0	3	MTE ****	Program Elective – II / Minor Specialization	3	0	0	3
	IPE 4302	Open Elective -1 Creativity, Problem Solving and Innovation				3	*** ****	Open Elective – II				3
	MTE 3141	Drives, Controls and Modelling Lab	0	0	3	1	MTE 3241	Hydraulics Lab	0	0	3	1
	MTE 3142	Robot Operating System Lab	0	0	3	1	MTE 3242	IIoT Lab	0	0	3	1
							MTE 3243	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 / Minor Specialization	3	0	0	3	MTE 4291	Industrial Training				1
	MTE ****	Program Elective – IV / Minor Specialization	3	0	0	3	MTE 4292	Project Work/Practice School				12
	MTE ****	Program Elective – V	3	0	0	3	MTE 4293	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 4191	Mini Project (Minor Specialization) *				8						
			15	0	0	18/26						13/ 33
	Total Contact Hours (L + T + P) +OE		15 + 3 = 18									

Minor Specialization		
I. Electric Vehicle Technology ELE 4415: EV Battery Technology and Power Train Development	VI. Computational Mathematics MAT 4401: Applied Statistics and Time Series Analysis	MTE 4453: Embedded Systems and RTOS MTE 4454: Engineering Materials MTE 4455: Fractional Order Modelling and Control

<p>AAE 4420: EV Product Development, Homologation and Hydrogen FCEV ELE 4417: EV Vehicle Design and Analysis AAE 4421: EV FEA Analysis</p> <p>II. Industrial IoT Systems MTE 4405: Database Management Systems MTE 4406: Cyber Security for Industrial Automation MTE 4407: Internetworking for Industries MTE 4408: Principles of Cryptography</p> <p>III. Robotics and Automation MTE 4409: Artificial Intelligence for Robotic Vision MTE 4410: Robot Dynamics and Control MTE 4411: Robot Path Planning and Mobile Robots MTE 4412: Soft Robotics</p> <p>IV. Micro and Nano Systems MTE 4413: Semiconductor and VLSI systems MTE 4414: Smart Materials for Micro and Nano Systems MTE 4415: Design of Micro and Nano Devices MTE 4416: Fabrication and Testing of Micro Systems</p> <p>V. Precision Agriculture Technology MTE 4417: Smart Farming Machinery MTE 4418: Robotics and Automation in Agriculture MTE 4419: Food Process Automation MTE 4420: Digital Agriculture</p>	<p>MAT 4402: Computational Linear Algebra MAT 4403: Computational Probability and Design of Experiments MAT 4404: Graphs and Matrices</p> <p>VII. Business Management HUM 4401: Human Resource Management HUM 4402: Marketing Management HUM 4403: Financial Management HUM 4404: Operations Management</p> <p>Other Program Electives MTE 4441: Antennas, Radar and Navigation MTE 4442: Augmented Reality and Virtual Reality MTE 4443: Autonomous Mobile Robotics MTE 4444: Biomechatronics MTE 4445: Building Automation MTE 4446: Cloud Computing MTE 4447: Data Analytics and Machine Intelligence MTE 4448: Data Mining and Visualization MTE 4449: Digital Manufacturing MTE 4450: Deep Learning for Computer Vision MTE 4451: Design of Mechanical Drives MTE 4452: Electric Vehicles</p>	<p>MTE 4456: Human Robot Interaction MTE 4457: Machine Learning MTE 4458: Machine Tool Technology MTE 4459: Machine Vision MTE 4460: Mechanical Vibrations MTE 4461: Micro and Nano Fabrication of Electronic Devices MTE 4462: Micro Electro Mechanical Systems MTE 4463: Micro-manufacturing Systems MTE 4464: Nanotechnology MTE 4465: Object Oriented Programming using Python MTE 4466: Production and Operations Management MTE 4467: Reinforcement Learning for Robotics MTE 4468: Renewable Energy Technology MTE 4469: Sustainable Manufacturing MTE 4470: Systems Modelling and Simulation MTE 4471: Wireless Sensor Networks</p> <p>Open Electives MTE 4311: Autonomous Mobile Robots MTE 4312: Farm Automation MTE 4313: Hydraulics and Pneumatics Systems MTE 4314: Industrial IoT MTE 4315: Introduction to Industrial Robotics</p>
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*Applicable to students who opted for minor specialization

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



**DETAILED SYLLABUSES FOR 2022
CURRICULUM
DEPARTMENT OF MECHATRONICS**

III SEMESTER

MAT 2121: ENGINEERING MATHEMATICS III [2 1 0 3]

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

CLO1	Solve the boundary value 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.

Vector Calculus: **[12]**

Gradient, divergence and curl, their physical meaning and identities. Line, surface and volume integrals. Green's theorem, statements of divergence and Stoke's theorems, applications.

Fourier series: **[10]**

Fourier series of periodic functions, Euler's formulae. Fourier series of odd and even functions and functions with arbitrary period. Half range expansions. Fourier integrals. Sine and cosine integrals, Fourier transform, Sine and cosine transforms. Harmonic analysis.

Partial differential equations: **[08]**

Basic concepts, solutions of equations involving derivatives with respect to one variable only. solutions by indicated transformations and separation of variables. Derivation of one-dimensional wave equation (vibrating string) and its solution by using the method of separation of variables. D'Alembert's solution of wave equation. Derivation of one-dimensional heat equation using Gauss divergence theorem and solution of one-dimensional heat equation. Solution by separation of variables.

Numerical Methods: **[10]**

Finite difference expressions for first and second order derivatives (ordinary and partial). Solution of boundary valued problems, Classification of second order partial differential equations. Numerical solutions of Laplace and Poisson equations by standard five point formula 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 2121: 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 for data handling operations.
CLO2	Appraise the data structures and their properties for different industrial applications.
CLO3	Appraise the time complexity of algorithms and sorting techniques for data handling operations.
CLO4	Implement text processing algorithms on applications for pattern searching in a text.
CLO5	Analyse the algorithms for graph search on various real-time problems.

Introduction to Python Programming: [08]

Data types. I/O statements, Conditional and Looping statements, Functions

Programming using Data structures: [10]

Stacks, Queues, Evaluation of expressions, Linked lists-singly, doubly, header node, circular along with application.

Searching operations: [05]

Trees- Binary trees, In order, Preorder and Post order traversal of Trees. Creation, Insertion and Deletion operations on Binary search tree. Searching – Linear search, Binary search.

Sorting operations: [06]

Sorting – Bubble sort, Selection sort, Merge sort, Quick sort, Heap sort.

Introduction to Algorithms: [07]

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 2122: DIGITAL DESIGN AND VERILOG PROGRAMMING [2 0 1 3]

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

CLO1	Develop 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	Evaluate the digital implementation options and architecture of FPGAs.
CLO5	Analyse the principles of engineering ethics, sustainability, environmental health, safety, hazards in semiconductor industries.

Logic Design Fundamentals:

[02]

Logic Families - Transistor-transistor logic (TTL) and CMOS logic, Performance metrics of logic gates, Review of logic minimization techniques, Weighted and unweighted codes.

Combinational Logic Design:

[08]

Half-adder, full-adder, Binary Adder/ Subtractor, BCD Adder, code converters, Binary comparators, Parity generator/ checker.

Combinational circuit design using logic blocks : multiplexers, demultiplexers, encoders, priority encoder, decoder

Pre-requisite: Boolean algebraic expression minimization, K-map reduction

Self-learning: Shannon's decomposition

Sequential Logic Design:

[08]

Latches, Flip-flops: SR, D, JK and T, Master-slave JK flip-flop, Design of synchronous and asynchronous counters (Up/down arbitrary counter, Ring and Johnson counter etc.), shift registers: types, universal shift register, Synchronous Sequential machines: classification, finite state machine (FSM), analysis and design, state minimization, state assignment.

Verilog HDL:

[14]

Introduction to HDL, VHDL versus Verilog, language constructs and conventions

Structural modeling: Gate level modeling - gate primitives, module structure, array of instances of primitives, delay

Data-flow Modeling: Continuous assignment structure, delays and continuous assignments, assignment to vector, operators.

Behavioral Modeling: Operations and assignments, constructs like initial, always, wait, if, if-else, case, assign, repeat, loop statements, blocking and non-blocking assignments.

Switch Level Modeling: basic transistor switches, CMOS switches, bidirectional gates

Tasks and Functions: parameters, path delays, module parameters. system tasks and functions, user defined primitives (UDF).

Applications: State Machine, Calculator, Traffic Light Controller, Elevator

Testing Verilog model: Test Bench

Digital Implementation Options and FPGA Architectures: [04]

Full-custom and semi-custom design styles, PLD, ASICs: CPLDs, MPGAs and FPGAs, Architecture of ACTEL and XILINX logic family. Logic module, switching technology.

Self-study:

E-waste management, Environmental impacts of semiconductor manufacturing, Safety and Hazards in semiconductor industry, semiconductor industries for sustainable future

Pre-Requisite:

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 2123: DIGITAL AND ANALOG CMOS DESIGN [3 0 0 3]

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

CLO1	Construct combinational circuits using switch logic and gate logic with CMOS style.
CLO2	Analyse the CMOS fabrication process.
CLO3	Construct the circuits using analog building blocks for a specific function.
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.
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Introduction to CMOS: [02]

Moore's law, VLSI technology trends, BJT versus MOS device, MOSFET: depletion and enhancement type, VI characteristics and regions of operation, equation for drain current, concept of threshold voltage, aspect ratio, second-order effects.

CMOS Digital Design: [06]

NMOS versus CMOS process, NMOS and CMOS inverter-transfer characteristics, pass transistors and transmission gates, CMOS circuit realisation of Boolean functions and combinational circuits using switch logic and gate logic, Dynamic and clocked CMOS logic.

CMOS fabrication process: [04]

P-well, N-well process, Twin-tub process, Stick diagrams, Layouts, sheet resistance, standard unit of capacitance, delay unit, CMOS inverter delay.

Analog Circuit Design: [02]

Analog versus digital, Analog building blocks: Current Mirror: current sink and current source, Voltage feedback op-amp (VFOA) and Current feedback op-amp (CFOA), second generation current conveyor (CCII), Operational Transconductance Amplifier (OTA).

Self-learning: Applications of CCII, OTA

Operational Amplifier and applications: [18]

Operational amplifier and block diagram representation, ideal and practical characteristics, Open loop and closed loop operation.

Linear applications: voltage follower, summing amplifier, difference amplifier, V-to-I converter, I-to-V converter, integrator, differentiator, instrumentation amplifier.

Non-linear applications: Precision rectifiers, peak detector, sample and hold circuit, log and antilog amplifiers, analog multipliers and dividers, comparators, zero-crossing detector, window detector, Schmitt trigger, Square wave, triangular wave generator using opamps.

Active filters: Design and analysis of first and higher order low-pass, high-pass, band-pass, band-stop and all-pass active filters.

Self-learning: G_m -C analog filters

Data converters: [04]

Digital-to-analog converter (DAC) and Analog-to-digital converter (ADC), Binary weighted, R-2R DAC, Charge scaling DAC, Multiplying DAC, Flash type ADC, Successive approximation type ADC, Specifications of ADC and DAC.

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 2124: 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:

[04]

Definition of robots; Degrees of freedom; Degrees of movements, Robot configuration; Definition and factor affecting the control resolution, Spatial resolution, Accuracy and Repeatability, Specification of a robot, Actuators and Sensors, Drives and Transmission systems used in robotics

Coordinates, Mapping and Transformations:

[07]

Descriptions- Positions, Orientations, and Frames, Mappings-changing descriptions from frame to frame, operators: translations, rotations, and transformations, Homogeneous transformations, Inverting transforms, Fixed and Euler angles representation, Quaternions.

Forward Kinematics:

[06]

Introduction to kinematics, link and joint description, kinematic pair, open and closed kinematic chains, convention for affixing frames to links, manipulator kinematics, Joint space, and Cartesian Space, Forward kinematics of single and multi-degree of freedom industrial manipulators, frames with standard names. Kinematic modeling of planar and spatial parallel manipulators, Closed-loop equation, four-bar and slider-crank mechanism, Stewart platform

Inverse Kinematics and Differential Motions: [09]

Solvability, the notion of manipulator subspace, algebraic solution by reduction to polynomial, Pieper's solution for three axis, Inverse manipulator kinematics, the standard frames, solving a manipulator, repeatability, and accuracy. Inverse Transforms method i.e Pre and Post multiplication approach. Jacobian and inverse Jacobian, Cartesian and Joint space velocity, resolved motion rate control method, Resolved rate strategy, the Jacobian matrix for positioning, Velocity analysis through Jacobian matrix, Singularities in industrial arms, Differential Motions.

Robot Dynamics: [06]

Introduction, acceleration of a rigid body, mass distribution, Lagrangian Formulation of Dynamics, Euler's equation iterative Newton-Euler dynamic formulation, iterative vs. closed form, formulating manipulator dynamics for planar and spatial industrial manipulators. Introduction to 3D rigid body dynamics

Trajectory generation: [04]

Introduction, general considerations in path and trajectory description and generation, joint-space schemes Cartesian-space schemes, geometric problems with Cartesian paths.

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 2125: 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.

Basic Measurement Concepts: [06]

Units and standards, calibration, sensors and transducers, active and passive sensors, static and dynamic characteristics of an instrument, error analysis, electromechanical instruments.

Measurement of electrical quantities: [06]

Analog and digital voltmeters, ammeters, measurement of resistance, DC bridges, AC bridges, LCR-Q meter, cable fault detection- short circuit, open circuit, shielding and grounding methods.

Sensors and Transducers: [14]

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. Material science concepts: materials used for manufacturing sensors and transducers.

Data Acquisition and Signal Conditioning: [06]

Introduction to data acquisition, elements of data acquisition system, concept of signal conditioning- filters, amplifiers, attenuation, linearization, electrical isolation, surge protection, digital storage oscilloscope.

Standards and Ethics in measurement : [04]

IEC, ISO, IP standards, Electrical safety considerations, Engineering ethics, and Ethical aspects of technical risks, Case study.

Prerequisite:

Understanding of physics, solving basic electrical circuits

Self study:

Risk 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 2141: 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 and raspberry pi
CLO2	Implement Robot vision applications with OpenCV
CLO3	Develop graphical solutions for robotics work cell and program robot manipulator using teach-pendant.
CLO4	Develop applications with industrial and collaborative robots through teach pendant based programming
CLO5	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 Sherlock or Open CV.

Self-study:

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 2142: 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.

Linear and non-linear applications of Op-Amp using 741 IC. Timer circuits using 555 IC. Voltage regulator using 78xx, and LM317 ICs. 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 2143: 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*, Dhanpat Rai & Sons, New Delhi.

FOURTH SEMESTER

MAT 2231: 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.

Difference Equations and Z-transform: [06]

Difference equations representing physical systems, solution of difference 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: [10]

Series solutions of ordinary differential equations, Series solutions of Bessel's and Legendre's differential equations, expressions for $J_n(x)$ and $P_n(x)$, Rodrigues's formula for $P_n(x)$ Recurrence relations and generating functions for $J_n(x)$ and $P_n(x)$. Orthogonal properties of Bessel's functions and Legendre's Polynomials.

Theory of probability, random variables and Probability Distributions: [12]

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.

Random variables: [12]

Two and higher dimensional random variables, Covariance, correlation coefficient, regression lines, least square principles of curve fitting. Moment generating function, Functions of one dimensional and two dimensional 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 2221: 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
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Introduction to mechanisms and machines: [08]

Kinematics and Dynamics, Mechanisms and Machines, Plane and Space Mechanisms, Kinematic Pairs, Kinematic Chains, Kinematic Diagrams, Kinematic Inversion, Four Link Planar Mechanisms and their Inversions. Mobility and range of movement - 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: [06]

Velocity and Acceleration analysis, Corioli's component of acceleration. Dimensional synthesis of mechanism; motion, path and function generation, precision point approach, Chebyshev spacing, Three position synthesis, branch and order defects.

Balancing and Dynamic force analysis: [07]

Static and dynamic Balancing, balancing of several masses in different planes, Power Smoothing by Flywheels.

Gears and Gear trains: [09]

Gears – terminology, fundamental law of gearing, involute profile. Interference and undercutting, minimum number of teeth, contact ratio, bevel helical, spiral and worm gears .Gear Trains – simple, compound and epicyclic gear trains; sliding gear boxes and synchronous, gear boxes.

Cams and followers: [06]

Classification of cams and followers, Displacement, Velocity & acceleration-time curves. Displacement diagrams involving simple harmonic motion, uniform velocity motion, uniform acceleration and deceleration motion and cycloidal motion. Cam profile diagrams of disc cam with knife edge follower, roller follower, flat foot mushroom follower and basic concepts of roller oscillating follower.

Self-Study:

Mechanisms used in robotic applications and analysis of velocity and acceleration of various 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 2222: 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: [05]

Review of stresses, strains, shear force and bending moments. Types of loads and stresses, Uniaxial biaxial and complex loading systems, stresses along inclined plane, principal planes and principal stresses

Bending and Torsional Stresses: [05]

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, stepped and hollow shafts, Combined loading, Theories of failures

Deflection of Beams: [04]

Deflection of beams by double integration method and Macaulay's method.

Static and Dynamic Loading: [05]

Stress concentration, fatigue strength, stress-life (S-N) diagram, high cycle fatigue, endurance limit modifying factors, effect of mean stress, fluctuating stresses, and stresses due to combined loading.

Design of Transmission Shafts: [05]

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: [05]

Helical coil spring: compression springs of round/square/rectangular wires, spring materials, stress and deflection of spring subjected to steady, fluctuating and impact loads, spring surge and buckling, concentric springs.

Power Screws: [05]

Power Screws: Types of power screws, terminology, torque for power screws, collar friction, efficiency, nut for the power screw, stresses in power screws. Features and specification of electric screw jacks.

Design of Spur Gears: [05]

Spur gears, terminology, tooth profile, pressure angle, Lewis equation for beam strength, form factor, velocity factor, design for static loads, design for dynamic and wear loads.

Selection of Bearings: [05]

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.

Miscellaneous Topics: [04]

Sensing and measurement of mechanical motion, computer programs to calculate stresses and deflection in simple machine members.

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, New Delhi, 2007

MTE 2223: 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 on industrial automation:

[04]

Types of Automation; Architecture of Industrial Automation Systems, Industrial revolutions, Advantages and limitations of Automation, Trends in industrial automation, Automation components, case studies.

Sensors and actuators for automation:

[08]

Sensors, Transmitters, Actuators and Signal Conditioning: Measurements on Industrial sensor and actuator, Data Acquisition Systems. Hydraulic and Pneumatic components and its working principle, Dives and motors: Types of motors and Drives(VFD, Servo Drives). Case studies.

Industrial Controllers:

[12]

PLC, PID, DCS: Programmable controllers, Programmable logic controllers, Analog digital input and output modules, PLC programming, Ladder diagram, Sequential flow chart, PLC Communication and networking, PLC selection, PLC Installation, Advantage of using PLC for Industrial automation, Application of PLC to process control industries. Overview of DCS, DCS communication Supervisory Computer Tasks, DCS integration with PLC and Computers, Features of DCS, Advantages of DCS. Working principle of PID and its application.

Industrial monitoring components:

[03]

HMI and SCADA and case studies on monitoring station

Industrial Communication and networking:

[03]

Device network: CAN, PROFIBUS-PA, HART, CC-link Control network: ControlNet, PROFIBUS-DP, Ethernet, Interfaces: RFID, Barcode.

Overview of Industrial robots:

[04]

Types of industrial robot, components of robot, programming and industrial robot demo

Safety instrument used in robot and automation technology, Advancement in industrial automation:

[02]

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, *Industrial 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 2224: 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.

Introduction & mathematical modeling of physical systems:

[08]

Feedback control systems terminologies, types of system configuration, control system design Differential equation of physical systems (electrical, mechanical, electromechanical, systems with gears), Transfer function representation, State space representation of physical systems.

Time domain analysis:**[10]**

System characteristics: Poles and zeros of a system, first and second order system response analysis, time domain specifications, Steady state error (SSE) specification, SSE for non-unity feedback systems, generalized error series. Performance analysis: Stability, RH criteria, Root locus technique-construction and interpretation of system behavior

Frequency domain analysis :**[10]**

Concept of frequency response, Asymptotic approximation, Bode plot construction and interpretation of system behavior, frequency domain specification: gain margin , phase margin, relation between time domain and frequency domain specification, SSE characteristics from frequency response, modeling of time delay.

Compensators and controllers:**[08]**

Effect of addition of poles and zeros on system response, introduction to compensator design and design of lag, lead, lag-lead compensating network, Introduction to P, PI, PID controllers, and Controller tuning methods.

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 2225: 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
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Introduction to Microcomputer: [01]

Significance and History of Microcomputer Technology, Basic function of Microcomputer Control.

Introduction to ARM Cortex M series: [04]

History of ARM Cortex M series, RISC CPU Architecture. Programming model- Internal Memory and External Memory, Types of registers, stages of pipeline.

Instruction set and Programming: [12]

Addressing mode – immediate, register, direct and indirect, base addressing. MSP432 instruction set – Data transfer instructions, Arithmetic instructions, program flow and branch instructions, Data exchange, array, signed operations, Logic and Bit instructions, stack pointer operations. Subroutines. Delay calculation and programming.

Introduction to ARM Programming: [17]

Programming ARM in C. Data types in embedded C, arithmetic and logic operators, control statements and loops in embedded C, functions and arrays, GPIO programming, timers and counters, Interrupts. Interfacing of MSP432. Nested Vector Interrupt Controller, Timer 32, Timer A, PWM generation, Clock select, UART, Generation of Baud rate.

Case studies: [02]

ARM based system development.

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 2241: 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.
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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 publishers, Delhi 2002.
4. Narayana K.L. and Kannaiah P, *Text Book on Engineering drawing*, Scitech Publications, Chennai 2002.

MTE 2242: 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 2243: 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.

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.

Self-study:

Siemen and Allen Bradely manual

<https://instrumentationtools.com>

FIFTH SEMESTER

HUM 3021: 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: **[09]**

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.

Economic Analysis of Alternatives: **[17]**

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. Minimum Cost Analysis.

Depreciation: **[02]**

Physical & Functional Depreciation, Methods of Depreciation - Straight Line, Declining Balance, Double-Declining balance method, Sum-of-the-Years Digits, Sinking Fund and Service Output Methods, Case Study.

Financial Statement Analysis: **[06]**

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 of Financial Statement Analysis.

Project Risk: **[02]**

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 3121: 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 Signals and Systems:

[12]

Signals, Systems, Signal Processing, Basic signals, operations, and properties, System Properties, Impulse Response, convolution, Transform domain analysis of discrete-time systems: Z-transform - Definition and properties, region of convergence, inverse Z-transform, transfer function, poles and zeros, application of Z-transforms to discrete time systems, Sampling, Aliasing

Self study: Properties of Z transform

Computation of DFT:

[06]

Frequency domain analysis of discrete time signals, Discrete Fourier Transform (DFT), Properties of DFT, Convolution using DFT. Fast Fourier Transform (FFT)

Self study: DTFT

IIR Filter Design:

[06]

Characteristics of IIR filters, Classical filter design using Butterworth approximation. Bilinear transformation, Frequency transformation technique for low-pass, high-pass, band-pass and band-stop filter design

Self study: Implementation of simple filter design using any software

FIR Filter Design: [06]

Characteristics of FIR filters, Window method, Optimal FIR design.

Digital Filters: [04]

Characteristics of digital filters, Digital filter structures – Direct, cascade, and parallel structures, FIR and IIR filters, Lattice structures

Case study: [02]

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. Schaffer, *Discrete time signal processing*, (3e), Prentice-Hall, 2014.
3. Proakis J.G. and D.G. Manolakis, *Digital Signal Processing: Principles, Algorithms and Applications*, (4e), PHI, 2007.
4. Sanjit K.Mitra, *Digital Signal Processing – A computer based approach*(4e), McGrawHill Education, 2013
5. Rabiner L.R and Gold D.J, *Theory and Applications of Digital Signal Processing*, (2e), Prentice Hall, 2007.

MTE 3122: 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: [05]

Basic components of electric drive, advantages, choice and current status of electric drives. Speed – torque conventions, multi-quadrant operation of electric drives, steady state equilibrium,

equivalent moment of inertia and torque. Motor duties and determination of motor power rating. Closed loop speed control.

Introduction to Power Electronics: [10]

Significance of power electronics. Power electronic devices – power diode and types, SCR – V-I characteristics, triggering methods. BJT, MOSFET and IGBT, Uncontrolled and controlled Rectifiers – RL loads, RLE loads with freewheeling diodes, dual converters. DC-DC Choppers, DC-AC Inverters – 1ph and 3ph with 120deg and 180deg conduction mode. AC-AC voltage regulators and cycloconverters.

DC Motor Drives: [10]

Principle of operation, EMF equation, types of motors, DC – series, shunt, separately excited, compound, basic equations, motor constants, torque speed characteristics, starting – conventional starters & soft starters, braking – regenerative and dynamic braking, speed control concepts, solid state motor drivers – choppers – Class A, B, C, E, single phase thyristor controlled rectifier – RLE load.

AC Motor Drives: [15]

Three phase motors, principle of operation – Rotating Magnetic Field (RMF), types of induction motors, slip ring, squirrel cage, basic equations, torque speed characteristics, starting – conventional starters, soft starters, braking – regenerative and dynamic braking, speed control- v/f control and vector control concepts. Single phase induction motors- types, torque speed characteristics. Synchronous motors – working principle, characteristics.

Advanced Electric Drives: [08]

Linear Induction and Synchronous motors, PM Synchronous Motors (PMSM) and BLDC motors. Switched reluctance motors and synchronous reluctance motor. Stepper motor – types , Universal motor, Servo motor - construction, torque- speed characteristics, applications, merits and demerits.

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. Bimbira 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.

FLEXICORE – 1 : MTE 3123: 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: [04]

Types of manufacturing processes and their operating principles, tooling, quality issues in manufacturing processes.

Computer Numerical Controlled Machines tools: [12]

Components of CNC Machines, Classification, Construction details of CNC machines, Machine structure, Guide ways, Spindle, Measuring systems, Drives and Controls - Spindle drives, feed drives. Configuration of CNC system, Interfacing, Monitoring, Diagnostics, machine data, Compensations for machine accuracy, Adaptive control CNC systems. Testing of CNC machines: Installation, maintenance, Testing and performance Evaluation of CNC machines, CNC programming using G and M code.

Advanced Manufacturing techniques: [08]

Non-Traditional Machining: Abrasive Jet Machining, Ultrasonic Machining, Electro Chemical Machining, Laser and electron beam machining, Electro Discharge Machining. – principles of operation and discussion of process variables.

Additive Manufacturing: [12]

Introduction to Additive Manufacturing, Fundamentals of Additive Manufacturing, Process Chain for Additive Manufacturing Processes, Benefits of Additive Manufacturing – Direct Benefits and Indirect Benefits. Rapid Prototyping Data Formats – STL Format, STL file problems – Missing facets, Degenerate Facets, Overlapping facets, Non – Manifold Conditions. Liquid Based Process – Stereolithography, Rapid Freeze Prototyping. Solid Based Process - Laminated object manufacturing (LOM), Fused deposition modelling (FDM). Powder Based Process - Selective laser sintering (SLS), Laser engineered Net shaping (LENS). Rapid Tooling - Silicon Rubber Moulding, Metal Arc Spray System, Investment casting, Direct Metal Deposition. 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.
5. Jagadeesha T, *Non-Traditional Machining Processes*, I K International Publishing House Pvt. Ltd, 2016.

FLEXICORE – 1 : ELE 3127: FOUNDATIONS OF EV & HYBRID VEHICLES [3 0 0 3]

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

CLO1	Apply the fundamental principles of Science and Engineering and study the performance characteristics of electric and hybrid vehicles.
CLO2	Relate the environmental impact, sustainability aspects, and policy/regulatory dynamics of electric and hybrid vehicles.
CLO3	Demonstrate knowledge of charging infrastructure, power management systems, and emerging trends in the electric and hybrid vehicle field.
CLO4	Illustrate the component level integration of Electric Vehicles.

Principles for Electric Vehicles [06]

EV Industry, EV Technology and Automotive Revolution, Electrical Engineering for EV, Battery Technology

Control system for Electric Vehicles [08]

Motor and Controller Systems, EV Numerical Calculations, EV Charging Infrastructure, Practical session - Well-to-wheel analysis of EV architecture

Essentials for Electric Vehicles [06]

Electrical Requirement, Power Distribution Specifications, Electronic Control System, Practical session - EV connection and system analysis

Types of components in Electric Vehicles [07]

EV Standards and Classifications, Selection for Electrical and Electronic Components, Practical session - EV hardware components

Principles for Hybrid Vehicles

[09]

Introduction to Hybrid Vehicles, Battery Chemistry, Efficiency, Definition and Parameters for Hybrid Systems, Electric Motors, Generators and Power Electronics for Hybrid Systems, Control Systems, Hybrid Electric Vehicle Operation, Practical session - Numerical study on powertrain sizing of HEV

References

1. James Larminie and John Lowry, "Electric Vehicle Technology Explained", 2nd Edition, Wiley-Blackwell, 2012.
2. Iqbal Husain, "Electric and Hybrid Vehicles: Design Fundamentals" 2nd Edition, CRC Press, 2010.
3. Beate Müller, Gereon Meyer, "Electric Vehicle Systems Architecture and Standardization Needs" 1st Edition, Springer International Publishing AG, 2015.
4. Yangsheng Xu , Jingyu Yan, Huihuan Qian, Tin Lun Lam, "Hybrid Electric Vehicle Design and Control: Intelligent Omnidirectional Hybrids" 1st Edition, McGraw Hill, 2013.
5. Gonzalo Abad, "Power Electronics and Electric Drives for Traction Applications" 1st Edition, Wiley, 2016

MTE 3124: 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:

[02]

Advantages and limitations, 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:

[04]

Various types of single acting and double acting cylinders, Types of 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, Fixed and variable type one and two way flow control valves, Dual pressure valve, shuttle valves, Time delay valves, Pressure sequence valves, pneumatic counter. Symbols of pneumatic valves,

Manual pneumatics: [08]

Traverse time diagram, Design of manually operated Direct and indirect control of actuators, control of single and multiple actuators along with use of position sensors, Circuits with AND,OR and time delay logic, control of multiple cylinders, Design of pneumatic circuits using classic, Cascade and Step counter approaches.

Electro-pneumatics components and sensors [04]

Electrically actuated direction control valves, Relay control systems, Limit switches, magnetic, inductive sensors, Capacitive, optical, ultrasonic, pneumatic proximity sensors, Symbols of electrical components. Application circuits using electronic sensors. Logic circuit design using K-V mapping.

Introduction to Hydraulic systems: [04]

Advantages and limitations, Physical principles of oil hydraulics, Hydraulic power pack, Types of hydraulic pumps: Axial, Radial piston pump, Rotating cam radial type pump, gear pump, Vane pump, unbalanced vane type, Balanced vane pump, Pump specifications.

Hydraulic actuators, valves and accessories: [10]

Linear actuators, force and power calculation, Rotary actuators, Accumulator, Check valve, pilot operated check valve, Pressure control valves: Direct acting and Compound relief valve, Break valve, Sequence valve, Pressure reducing valve, Flow control valves, Pressure compensated flow control valve and direction control valves.

Hydraulic circuits: [04]

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 3141: 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 3142: 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_Compiter 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 3022: 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

Introduction: [06]

Introduction to Business, Industrial Business, Classification of Industries and Job Opportunities (referring the industries visiting our campus). Who is a manager?, brief discussion on classification of managers (i.e. top, middle and lower), managers and administrators, definitions of management. Functions of Managers/Management and time spent on various managerial functions by managers at various levels, two characteristics of managerial functions, Efficiency and Effectiveness. Principles of Management by Henri Fayol. Three types of managerial responsibilities. Managerial Skills, roles played by managers (as per Mintzberg), Systems Approach to Management.

Planning: [05]

Types of Planning: General and Managerial; Strategic, Tactical and Operational. Nature and characteristics of planning. Types of Plans: Mission, Vision, Goals, Objectives, Policies, Strategies, Rules, Procedures and Programs. Steps in Planning. Management By Objectives: Process, Key Result Areas, guidelines in setting the objectives, qualitative and quantitative objectives, Stakeholders and their interests, Fiscal and Social Responsibilities. Strategic Planning: Planning Tools – SWOT, TOWS, Business Portfolio Analysis and Porter’s model; Process.

Organizing: [04]

Process, Principles of Organizing; Span of Control, factors affecting the span of control and levels. Departmentation: meaning, Types of Departmentation – by Function, Product, Customer, Geography, Time, Process, Simple numbers and combination. Types of managers – line, staff, functional and general. Structures – Line, Staff, Line and staff, Functional, Committee, Project and Matrix. Delegation – process and principles; Delegation and Decentralization. Formal and Informal organization.

Staffing: [06]

HRM and HRD, in brief – Job Analysis, Job Description and Job Specification; Recruitment – methods and sources; selection – process, techniques and instruments; Induction and Orientation. Systems Approach to Staffing; Managerial development and training programmes.

Leading: [07]

Meaning, differences between – leading and managing, leader and manager; motives, motivation and motivators. Theories of motivation – Maslow’s Need Hierarchy, Herzberg’s 2 – factor theory and McGregor X and Y theory; Motivational techniques. Leadership – theories, ingredients, and

styles based on authority, Likert's 4 systems of management and Leadership Grid. Communication – general and managerial, types of communication, barriers of communication.

Controlling: [02]

Process, Types of Control, Management Control Techniques – budgetary, non-budgetary and network; Types of budgets – financial, operational and non-monetary. Critical point Control Technique and standards. Direct and Preventive Controls.

Entrepreneurship, International Management Practices, Professional Ethics and Global Issues: [06]

Functions of an entrepreneur, types of entrepreneurs; traits and characteristics of entrepreneurs and entrepreneurs. Business Plan preparation. Nature, and purposes of international businesses and Multinational Corporations; Managerial practices in Japan and USA, and Theory Z. 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 - 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 3221: ENERGY AND HEAT TRANSFER [3 0 0 3]

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

CO1	Calculate the work, heat transfer and efficiency for the processes and refrigeration cycles using the basic principles of thermodynamics.
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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.

Basic Concept of Work and Heat: [07]

Basic definitions, different types of systems, thermodynamic properties, state, path and processes, Quasi static process, Gibbs Phase rule., Zeroth Law, Concept of thermal equilibrium. Concept of heat and work, types of work transfer- displacement work, paddle wheel work, flow work, shaft work, First law of thermodynamics, Concept of internal energy, Enthalpy, specific heats, Steady flow energy equation (SFEE), applications- Numerical Problems. Kelvin-Planck and Clausius statement, Carnot theorem, concept of entropy, Clausius inequality.

Applied Thermodynamics: [03]

Principles of refrigeration, Properties of refrigerants, Air refrigeration, Vapour compression cycles, Coefficient of performance.

Fluid Properties and Flow Characteristics: [05]

Units and dimensions, Properties of fluids - mass density, specific weight, specific volume, specific gravity, viscosity, compressibility, vapor pressure, surface tension and capillarity. Flow characteristics – concept of control volume - application of continuity equation, energy equation and momentum equation.

Fluid Flow: [06]

Laminar flow through circular conduits and circular annuli. Boundary layer concepts. Boundary layer thickness. Hydraulic and energy gradient. Darcy – Weisbach equation. Friction factor and Moody diagram. Commercial pipes. Minor losses. Flow through pipes in series and in parallel.

Heat Transfer- Introductory Concepts and Definitions: [03]

Modes of heat transfer-Basic laws governing conduction, convection, and radiation heat transfer, Thermal conductivity, convective heat transfer coefficient, combined heat transfer mechanism, Boundary conditions of 1st, 2nd and 3rd Kind.

Heat Conduction: [03]

One dimensional conduction equations in rectangular for plane and composite walls. Overall heat transfer coefficient. Thermal contact resistance. Derivation for heat flow and temperature distribution in plane wall. Critical thickness of insulation without heat generation.

Heat Transfer Applications:

[09]

Heat transfer in extended surfaces of uniform cross-section without heat generation, Long fin, and short fin with insulated tip and without insulated tip and fin connected between two heat sources. Fin efficiency and effectiveness. Classification of heat exchangers; overall heat transfer coefficient, fouling and fouling factor; LMTD, Effectiveness. Numerical problems. 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 A 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.

FLEXICORE – 2: MTE 3222: 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

Vehicle Body:

[03]

Vehicle construction and layouts – Full frame, Unibody, space frame; front section, central section and rear section parts; Vehicle sizes - compact, intermediate, full sizes. Engine Wheel Drive- Front engine front wheel, Front engine rear wheel and rear engine and rear wheel drive, All wheel drive.

Power system: [05]

Petrol, diesel, bio-diesel, electrical, hybrids, solar, fuel cell - concept and working principle. Fuel supply and fuel monitoring system.

Transmission systems: [10]

Clutch- friction clutches, electromagnetic clutches, dual clutches, hydrodynamic clutches. Manual transmission-Sliding mesh gearbox, constant mesh gearbox, synchro mesh gearbox. semi and fully-automatic transmission, Fluid drive, Epicyclic gearbox, freewheeling unit, torque convertor. Meshing Orders of Drivetrain Systems, Noise and Vibration Characteristics, differentials, limited slip differential. Automobile tyres and wheel alignment.

Steering and suspension systems: [08]

Power steering – Types-Hydraulic Power Steering System, Hybrid or Semi Hydraulic Power Steering System and Electric Power Steering System- components and working principle.

Suspension system - Conventional suspension system, Independent suspension system, Air suspension system, Hydro elastic suspension system – components- working principle

Braking system: [05]

Types – B=Drum and disc, mechanical, hydraulic, servo and air brakes. Minimum stopping distance with front wheel, rear wheel, and four wheel braking. Case study - electro-hydraulic braking for energy regeneration.

Miscellaneous: [05]

Industrial Fabrics - Textile structural composites for automotive parts, automobile interior and their recycling. Lighting circuit of an automobile. Heating and Air conditioning systems. Automobile electrical systems

Self-study:

Ergonomics for Automobile engineering, Safety standards as per ARAI, Sustainable practices in Automotive industries.

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.

FLEXICORE – 2: ELE 3225: AUTOMOTIVE MECHANICS FOR ELECTRIC VEHICLES [3 0 0 3]

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

CLO1	Interpret the fundamentals of vehicle dynamics
CLO2	Model Electric vehicle at modular levels
CLO3	Model Electric vehicle at System level
CLO4	Analysing modular level behaviour of Electric vehicles
CLO5	Analysing system level behaviour of Electric vehicles

Automotive Engineering & Vehicle Dynamics [07]

Vehicle Dynamics Fundamentals, Tire Mechanics and Dynamics, Suspension Systems, Braking Systems, Aerodynamics, Powertrain Systems, Vehicle Stability Control, Vehicle Safety, Vehicle Dynamics Simulation, Electric and Hybrid Vehicle Dynamics, **Practical session** - EV Dynamics & calculations

Sketching for Automotive EV Design [Software-based] [06]

Introduction to Automotive Sketching Software, Overview of Vehicle Design Process and Automotive Sketching, Basic Sketching Techniques and Tools in the Software, Sketching Car Exteriors, Interiors and Details, Creating Different Views and Angles of the Vehicle, Rendering and Presenting the Final Sketches, Understanding Proportions, Perspectives and Shapes in Automotive Sketching, Creating Sketches for Different Vehicle Types (Sedans, SUVs, and Trucks), Tips and Tricks for Automotive Sketching in the Software

Advanced EV Modelling Using SolidWorks Tool [Software-based] [08]

Introduction to EV Technology and Its Benefits, Basic Vehicle Design Principles, Design and Modelling of Chassis and Frame, Suspension Systems, Design and Modelling of Braking and Steering Systems, Design and Modelling of Electrical Components for EVs, Battery Pack Design and Modelling for 2, 3 and 4 Wheelers, Motor and Drivetrain Design and Modelling for 2, 3 and 4 Wheelers, Design and Modelling of Wheels and Tires for 2, 3 and 4 Wheelers, Testing and Simulation of Vehicle Performance Using Solid Works, Design for Manufacturability and

Assembly Considerations, Sustainability and Environmental Impact Considerations in EV Design,
Practical session - EV hardware components walkthrough

Multibody Dynamics with MSC Adams [Software-based] [08]

Introduction to MSC Adams Software and Its Capabilities, Setting Up the Modelling Environment in MSC Adams, Multi-body Dynamics Principles and Application to Vehicle Systems Modelling, Vehicle Suspension Systems Modelling, Vehicle Steering Systems Modelling, Vehicle Braking Systems Modelling, **Practical session** - EV Component design & modeling

EV Analysis with MSC Adams (Software-based) [07]

Tire Force and Characteristics Modelling, Vehicle Dynamics Analysis Including Simulating Ride and Handling, Vehicle Stability and Rollover Events, Optimisation Techniques for Vehicle Designs Using MSC Adams, Integration of MSC Adams Models with Other Software Tools for System-level, Simulations and Analysis, **Practical session** - EV body design analysis

References:

1. James Larminie and John Lowry, "Electric Vehicle Technology Explained", 2nd Edition, Wiley-Blackwell, 2012.
2. Gianfranco Pistoia, "Electric and Hybrid Vehicles: Power Sources, Models, Sustainability, Infrastructure and the Market" 1st Edition, Elsevier, 2010
3. Chris Mi, M. Abul Masrur & David Wenzhong Gao, "Hybrid Electric Vehicles: Principles and Applications with Practical Perspectives" 2nd Edition, Wiley Publications, 2017.

MTE 3241: 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 valve 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 3242: IIOT LAB [0 0 3 1]

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

CLO1	Examine communication protocols and the concepts of subnetting for process of Industrial automation design.
CLO2	Simulate 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	Implement a mini project on any IIoT application for real time automation.

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 3243: 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	Develop 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

SEVENTH SEMESTER

There are five program electives and one open elective with total of 18 credits to be taught in this semester.

EIGHTH SEMESTER

MTE 4291: 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 4292: 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, safety, ethics, commercial, economic, environmental and societal impact issues.
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 in a team or individually.
CLO3	Develop the ability to adopt a methodological approach to solve the task/design/problem in multi-disciplinary stream with appropriate consideration for public health, ethics, safety, environmental issues.
CLO4	Conduct experimentation, and testing to achieve the defined objectives through computing/coding/statistical analysis.
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

ELE 4415: EV BATTERY TECHNOLOGY AND POWERTRAIN DEVELOPMENT [3 0 0 3]

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

CLO1	Explain EV Battery Fundamentals
CLO2	Develop a BMS for EV
CLO3	Test for Battery Life-cycle

CLO4	Demonstrate EV Charging System
CLO5	Analyse the EV powertrain Components

Battery Fundamentals **[07]**

Basics of Batteries, Battery Parameters, Lithium-Ion Characteristics, Thermal Runaway Battery Management System (BMS), Functionality, Practical session - Battery Selection and Connection Process with Vehicle Sensors

Battery Management Systems **[05]**

SOC/SOH Estimation, Cell Balancing, Protection, Thermal Management, CAN Communication, **Practical session** - BMS development

Battery Pack Design & Modelling **[09]**

Overview of Battery & BMS System, Electrical Design, Mechanical Design: Calculations and Mechanical Design using ANSYS, Heat Transfer, Thermal Design of Battery Pack, Battery Pack Assembly and Test, Thermal Analysis on Battery Pack, MATLAB/Simulink-based Battery Pack Modelling, **Practical session** - Battery life cycle testing

Powertrain and Charging Systems of Electric Vehicles **[07]**

Introduction to EV Powertrain, Overview, Architecture and Components of EV Powertrain, Thermal Management of EV Powertrain, EV Charging Systems and Types of Chargers

Modelling, Simulation, and Analysis of EV Powertrain Components **[08]**

Modelling and Simulation of EV Powertrain Components in MATLAB, Modelling and Analysis of EV Powertrain Components in SolidWorks, Analysis of EV Powertrain Components in ANSYS, Case Study on Powertrain of Existing Models

References:

1. James Larminie and John Lowry, "Electric Vehicle Technology Explained", 2nd Edition, Wiley-Blackwell, 2012.
2. Sandeep Dhameja, "Electric Vehicle Battery Systems", Newnes Publisher, 1st Edition, 2001.
3. Christopher D. Rahn, "Battery Systems Engineering" 1st edition, Wiley, 2013.
4. Bruno Scrosati , K. M. Abraham , Walter A. van Schalkwijk , Jusef Hassoun, "Lithium-Ion Batteries: Advanced Materials, Technologies, and Applications" 2nd Edition, Wiley-Blackwell, 2013.
5. Emma Briec, Beate Müller, "Electric Vehicle Batteries: Moving from Research towards Innovation" 1st Edition, Springer International Publishing AG, 2016.

**AAE 4420: EV PRODUCT DEVELOPMENT, HOMOLOGATION & HYDROGEN FCEV
[3 0 0 3]**

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

CLO1	Interpret the various steps involved in the regulations and standards of Electric Vehicle
CLO 2	Demonstrate the certification process of EV
CLO 3	Experiment with the EV Product Development cycle
CLO 4	Illustrate the principles of Fuel cells
CLO 5	Organize the fuel-cell based Hybrid vehicle construction

EV Design, Manufacturing & Management [06]

Introduction to EV (2W, 3W & 4W) Market and Opportunities, Electric Vehicle Design Procedure and ICE Model, Introduction to EV Management (Categories, Regulations and Standards), EV Homologation and Testing, FAME India and Manufacturing Guidelines

EV Testing, Certification & Market analysis [08]

EV Certification Process, EV Charging, Electric Vehicles and Retrofitting, Motor Technology and EV Motor Market Analysis, EV Categories and Proposed Changes, EV Retrofitting Business, Battery Technology in EV, EV Battery Market Analysis, **Practical session** - Conducting a market analysis of the EV industry

EV R&D Product Development [10]

Introduction to Product Development Plan, Segment Selection, Product Design Plan, Product Validation Plan, Vehicle Dynamics Selection, Product Design Validation, Product Specification - Competitor Analysis, Selection of Off-the-Shelf Parts, Development Methods, Product Development Plan, Unit Economics, Design Feasibility, Design for Manufacturing, DFMEA and PFMEA, Business Plan, Product Launch, POC/MVP/Working Prototype, **Practical session** – Using the market research to develop a business plan for an EV manufacturer

Hydrogen Fuel Cells [06]

Introduction to Future Mobility, Why Hydrogen-based Technology, Essentials of Hydrogen, How Does Hydrogen Compare to Hydrocarbon Fuels in Terms of Energy, Flammability and Safety, Hydrogen Fuel Cells, Use of Hydrogen in IC Engines, Hydrogen Fuel Cell Techniques and Systems, Fuel Cell Engine Safety and Maintenance

Hybrid Vehicles & Fuel Cells [06]

Fuel Cell Hybrid Electric Vehicle Acts, Codes, Regulations and Guidelines, Maintenance and Fuelling Facility Requirements, Fuel Cells in Hybrid Electric Vehicles and Pure Electric Vehicles, Auxiliary Power Generation Using Hydrogen, Types of Fuel Cells and Techniques Used, Fuel Stack Module Construction

References:

1. James Larminie and John Lowry, “Electric Vehicle Technology Explained”, 2nd Edition, Wiley-Blackwell, 2012.
2. Tom Denton, “Electric and Hybrid Vehicles” 2nd Edition, CBS Publisher, 1905.
3. Chris Mi, M. Abul Masrur & David Wenzhong Gao, “Hybrid Electric Vehicles: Principles and Applications with Practical Perspectives” 2nd Edition, Wiley Publications, 2017.

ELE 4417: EV VEHICLE DESIGN & ANALYSIS [3 0 0 3]

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

CLO1	Illustrate the Electronics Components used in ECU
CLO2	Model Controller circuits using Proteus
CLO3	Understand the MATLAB tool principles
CLO4	Infer the various features of Simulink supporting Power modules of EV
CLO5	Model EV Battery

Introduction to Analog Electronics [08]

Introduction to Basic Electronics, Diode Fundamentals, Rectifiers and Filters, Power Electronics for EVs: Voltage Regulators, Inverters and Converters, Special Purpose Diodes, Transistors and Types of Transistors, Operational Amplifier (Op-Amp)

Fundamentals of Digital Electronics [08]

Digital Electronics, EV Control Systems, EV Communication Networks, Microcontrollers and Microprocessors, Introduction to Proteus Software, Circuit Development Using Proteus

Essentials for Designing and Simulation Using MATLAB [06]

Overview and Environment, Basic Syntax, Variables and Commands, Commands, M-files, and Types, Operators, Decision Making and Loops, Vectors, Matrix, and Arrays, Colon Notation and Numbers, Strings and Functions, Numbers, Plotting and Graphics, Algebra, Calculus, Differential, and Integration, Polynomials and Transforms, Programming EV Systems in MATLAB, Simulink and Fitting, Developing SIMULINK Models for Vehicle Units, Advisor and QSS Toolbox, QSS-based Vehicle Control, **Practical session** - Analyze and troubleshoot electronic circuits using simulation tools and lab equipment

EV Architecture Modelling Using MATLAB [Software-based] [08]

Motor Development and Induction Motor Characteristics, Simulink Model to Calculate Vehicle Configuration, Multi-level Inverter Design and Simulation, Solar PV-based Charger Development, DC-DC Converter, Modelling of Li-ion Battery Pack, Design of EV Using QSS Toolbox, Battery Thermal Modelling, BMS Modelling, Electric 4W Powertrain Modelling, **Practical session** - Data analysis and visualization using MATLAB for vehicle system

Design of EV System Using MATLAB [Software-based] [06]

Power Required to Overcome Resistance Forces Acting on the Vehicle, Power Converters in Electric Vehicles, Inverters in Electric Vehicles, Motor and Motor Controllers, Modelling of EV Battery and BMS, **Practical session** - Modeling and simulation of EV powertrain components, such as motors, controllers, and inverters, using MATLAB/Simulink

References:

1. James Larminie and John Lowry, "Electric Vehicle Technology Explained", 2nd Edition, Wiley-Blackwell, 2012.
2. Iqbal Husain, "Electric and Hybrid Vehicles: Design Fundamentals" 2nd Edition, CRC Press, 2010.
3. Ali Emadi, "Advanced Electric Drive Vehicles", 1st Edition, CRC Press, 2014.
4. Sandeep Dhameja, "Electric Vehicle Battery Systems", Newnes Publisher, 1st Edition, 2001.
5. Haitham Abu-Rub, Mariusz Malinowski, Kamal Al-Haddad, "Power Electronics for Renewable Energy Systems, Transportation and Industrial Applications" 1st Edition, Wiley-IEEE Press, 2014.
6. J Larminie "Electric Vehicle Technology" 2nd Edition, Wiley-Blackwell, 2012.

AAE 4421: EV FEA ANALYSIS [3 0 0 3]

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

CLO1	Model the structure of EV using ABAQUS & ANSYS
CLO2	Inspect the structural models of EV
CLO3	Analyze the structural characteristics of components using FEA
CLO4	Categorize Mechanical & electrical properties of materials and Computational FD of EV system
CLO5	Examine the transient analysis of EV

EV Design and Structural Analysis with Altair HyperMesh [07]

Theory of FEA/CAE, Introduction to HyperMesh, Creating and Modifying Geometry, Geometry Clean-up and Defeature, Introduction to 2D Meshing, Introduction to 3D Meshing, Element Quality, Mesh Edit, Introduction to Plastic Meshing, Introduction to 1D Meshing, Modal Analysis, Linear Static Analysis, Buckling Analysis, Connectors, **Practical session** - Optimization techniques using HyperMesh

ABAQUS in EV Engineering [Software-based] [07]

Introduction to Abaqus Software, Fundamentals of FEA-Stress, About Abaqus Software-Features, Applications of Abaqus Software in Different Industries, Simple Modelling in Abaqus Software, Create Material and Create Assembly, Create Steps, Loads, Boundary Conditions, Generate Mesh, Result Visualization, **Practical session** – Multiphysics analysis using Abaqus

Finite element Analysis of EV structural components [Software-based] [08]

One Dimensional Analysis, Linear Static Analysis and Linear Buckling Analysis, Heat Transfer Analysis, Non-linear Analysis, Dynamic Simulation-Modal Analysis, Impact Analysis, Time-Dependent Load Analysis

ANSYS in EV Engineering [Software-based] [07]

Basics of Finite-Element Analysis (FEA) along with ANSYS Tool and Software Interface, Essential Mechanical and Electrical Properties of Materials, Various Case Studies on ANSYS Mechanical, Basics of Computational Fluid Dynamics (CFD), Various Case Studies on ANSYS Fluent, **Practical session** – FEA analysis using ANSYS

Dynamic Simulation and Transient Analysis [Software-based] [07]

Simulation of Battery Thermal Management in Electric Vehicle, Vibration and Fatigue Analysis of Battery Pack, Simulation of Structural Integrity for Motor Mount, Thermal Analysis of Liquid-Cooled Radiator, CFD Study of External Cooling Mechanism for Battery Pack, **Practical session** - Vulnerability analysis

References:

1. James Larminie and John Lowry, “Electric Vehicle Technology Explained”, 2nd Edition, Wiley-Blackwell, 2012.
2. Erik Schaltz, “Electrical Vehicle Design and Modeling” 1st Edition, InTech Publisher, 2011.
3. J Larminie, “Electric Vehicle Technology”, 2nd Edition Wiley-Blackwell, 2012.
4. Jeff Strain, Ted Harris, Eric Miller, “Introduction to the ANSYS Parametric Design Language (APDL)”, 2nd Edition PADT, Inc., 2019.
5. Abaqus Analysis User's Guide by Dassault Systems Publisher: Dassault Systems ISBN: N/A (Available as part of the Abaqus documentation).
6. Patrick J. Roache, “Fundamentals of Computational Fluid Dynamics” Hermosa Pub., Revised Edition, Roache Publisher, Revised Edition, 2003.

INDUSTRIAL IoT SYSTEMS

MTE 4405: 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
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Introduction: [04]

Database-System Applications, Purpose of Database Systems, View of Data, Database Languages, Relational Databases, Data Storage and Querying, Transaction Management, Database Architecture, Database Users and Administrators.

Relational Model: [02]

Structure of Relational Databases, Database Schemas, Keys, Relational Query Languages, Relational Operations.

Database Design and the E-R Model: [04]

Overview of the Design Process, The Entity-Relationship Model, Constraints, Removing Redundant Attributes in Entity Sets, Entity-Relationship Diagrams, Entity-Relationship Design Issues, Extended E-R Features, Reduction to Relational Schemas.

SQL: [06]

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, Modification of the Database.

Relational Database Design: [04]

Features of Good Relational Design, Atomic Domains and First Normal Form, Decomposition Using Functional Dependencies, Functional Dependency Theory, Algorithms for Decomposition, Decomposition Using Multivalued Dependencies.

Transaction Management: [02]

Transaction Concept, A simple Transaction model, Storage Structure, Transaction Atomicity and Durability, Transaction isolation, Serializability.

Data mining: [08]

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, Approaches to mining multilevel association rules, correlation analysis, Issues and challenges in Data mining.

Clustering Techniques: [03]

Introduction, Clustering paradigms, Partitioning Algorithms, k – Medoid & k- means Algorithms, CLARA, CLARANS, Hierarchical Clustering, DBSCAN.

Classification and Prediction:**[03]**

Introduction, Tree Construction principle, Best Split, Splitting Indices, Splitting Criteria, Decision Tree Construction Algorithm, Tree pruning.

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.

MTE 4406: 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 the Principles of Security:**[06]**

Introduction to Security – Key Information Security Concepts; Critical Characteristics of Information; Components of an Information system; The Systems Development Life Cycle; Security Systems Development Life Cycle; Similarities and Differences between SDLC and SecSDLC; The Need for Security – Business Needs First.

Threats and Attacks:**[08]**

Threats; Attacks; Intruders – Intruder Behavior Patterns, Intrusion Techniques; Intrusion Detection – Audit Records, Statistical Anomaly Detection, Rule-Based Intrusion Detection, The Base-Rate Fallacy, Distributed Intrusion Detection, Honeypots, Intrusion Detection Exchange Format; Malicious Software – Types of Malicious Software, Viruses, Viruses Countermeasures, Worms.

Database Security Needs and Principles: [08]

Introduction to Database Security; SQL Injection; Reliability and Integrity; Database Disclosure – Sensitive Data; Inference; Multilevel Databases; Proposals for Multilevel Security; Designs of Multilevel Secure Databases.

Web security principles: [06]

Transport-Level Security – Web Security Issues, Secure Sockets Layer (SSL), Transport Layer Security (TLS); Electronic Mail Security – Pretty Good Privacy (PGP), Secure/Multipurpose Internet Mail Extension (S/MIME); IP Security – IP Security Policy, Encapsulating Security Payload, Internet Key Exchange.

Firewalls: [03]

The Need for Firewalls; Firewall Characteristics; Types of Firewalls – Packet Filtering Firewall, Stateful Inspection Firewalls, Application-Level Gateway, Circuit-Level Gateway.

Cyber Crimes and Hackers: [05]

Cyber Crimes – Cyber Criminals; Hackers – Hacking Topologies; 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 4407: 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 protocols.
CLO4	Enhance the learning of radio, infrared and satellite systems as LANs.

Introduction to Computer Networks: [05]

Types of networks, Types of transmission media, Concept and types of Multiplexing, Concept and types of Multiple Access techniques, Types of Transmission, Principles and types of Analog and Digital Modulation, Principle and types of Encoding, Need for data security, Error detection and correction techniques, Concepts and types of switching techniques.

ISO/OSI model: [10]

Introduction to networks in Process Automation, 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: [07]

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: [07]

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: [07]

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 4408: 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 to Cryptography: [04]

Security Goals; Security Attacks; Security Services; Security Mechanisms

Mathematics of Cryptography: [06]

Divisibility and The Division Algorithm; The Euclidean Algorithm; Modular Arithmetic – The Extended Euclidean Algorithm; Prime Numbers; Fermat’s and Euler’s Theorems – Fermat’s Theorem, Euler’s Totient Function, Euler’s Theorem; Testing for Primality; The Chinese Remainder Theorem.

Symmetric-Key or Private-Key Cryptosystems: [12]

Classical Encryption Techniques – Symmetric Cipher Model, Substitution Techniques, Transposition Techniques; Block Cipher Principles; The Simplified Data Encryption Standard (S-DES); The Data Encryption Standard (DES); Double DES (2DES); Triple DES (3DES); Modes of operation; Advanced Encryption Standard (AES) – AES Structure, AES Round Functions, AES Key Expansion; Stream Ciphers; RC4.

Public-Key Cryptosystems: [05]

Principles of Public-key Cryptosystems – Public-Key Cryptosystems, Applications for Public-Key Cryptosystems; The RSA Algorithm; Diffie-Hellman Key Exchange; ElGamal Cryptographic System.

Cryptographic Hash Functions: [05]

Applications of Cryptographic Hash functions – Message Authentication, Digital Signatures; Hash Functions based on Cipher Block Chaining; Secure Hash Algorithm – SHA-512; SHA-3.

Message Authentication and Digital Signatures: [04]

Message Authentication Requirements; Message Authentication Functions – Message Authentication Code; Digital Signatures – Properties, Attacks and Forgeries, Digital Signature Requirements, Direct Digital Signature.

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 4409: 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 Processing Fundamentals: [08]

Image Formation, Linear Filtering, Correlation, and Convolution, Visual Features: Edge, Blobs, Corner Detection Algorithms, SIFT, SURF, HOG, Geometric transformation, Implementation using OpenCV Libraries.

Convolutional Neural Networks: [12]

Perceptron, Delta learning rule, multi-layer perceptron, Backpropagation, optimizers and Regularization, Data augmentation, Introduction to CNN (Convolutional Neural Network), Evolution of CNN Architectures: LeNet, AlexNet, ZFNet, VGG, Inception Nets, ResNets, DenseNets, Implementation using Deep Learning Libraries.

Object Recognition, and Segmentation:

[10]

Background of Object Detection, CNN for Recognition and Detection, R-CNN, Fast R-CNN, Faster R-CNN, YOLO (You Only Look Once), SSD (Single Shot Detector), RetinaNet; CNNs (Convolutional Neural Networks) for Segmentation: FCN, SegNet, U-Net, Mask-RCNN Review of RNNs (Recurrent Neural Networks); CNN + RNN Models for Video Understanding. Implementation using Deep Learning Libraries.

Generative Models in Vision

[06]

Deep Generative Models: GAN (Generative Adversarial Networks), Cycle-GANs, Progressive GANs, StackGANs, Pix2Pix. Case Study: Image Editing, Inpainting, Super-Resolution, Image Restoration, 3D Object Generation, Implementation using Deep Learning Libraries.

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 4410: 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.
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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.

Introduction: [05]

Examples of robotic systems, Transformations: Joint/Task space, Forward kinematics, Inverse kinematics, Jacobians, Trajectory generation, Serial and parallel kinematics

Robot Dynamics: [11]

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: [11]

Regulator problem, tracking problem, controllers -PD, PID compensation, closed loop control, gain tuning, performance analysis, simulation analysis. Set point tracking – using PD and Feed forward control, Torque control, Computed torque control, Discretization of outer PD/PID Control loop, Actuator saturation, Integrator anti-windup compensation, Quadratic optimal control problem.

Nonlinear dynamics and control: [09]

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 4411: 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 Simultaneous 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:

[05]

Introduction, locomotion - key issues for locomotion, legged mobile robots, leg configurations and stability, examples of legged robot locomotion, wheeled mobile robots. Wheeled locomotion-the design space. Robot kinematics models and constraints, Mobile robot maneuverability- degree of mobility, Degree of steer ability, Robot maneuverability. Mobile robot workspace-degree of freedom, Holonomic robots, path & trajectory considerations. Motion control - open loop control Feedback control.

Configuration Space:

[05]

Obstacles space, dimensions of configuration space, topology of configuration space, parameterization, transformations, example configuration space. Potential functions – obstacle avoidance- additive and repulsive functions, gradient descent. Implementation in plane-computation, local minima problem.

Mobile control algorithms:

[05]

Analysis and complexity, running time, complexity, completeness. Visibility graph, Graph Search A*, Weighted A*, Anytime & Incremental Search D*, Road Maps - Generalized Voronoi Graph (GVG) - definition, properties, GVG – transversality, connectivity, opportunist path planning.

Cell decomposition:

[05]

Trapezoidal decomposition, Morse cell decomposition – variable slice, sensor-based coverage, complexity coverage, Visibility based decomposition. Sampling Based Algorithms – Probabilistic Road Map (PRM) – definition, sampling, connection strategies, Single query sampling planners,

Rapidly Exploring Random Trees (ERT), Control based planning, Manipulation planning, Optimal motion planning, Feedback motion planning.

Motion Planning: [03]

Motion planning under kinematics and dynamic constraints, Trajectory planning – Decoupled trajectory planning, direct trajectory planning, non-holonomic constraints, Path planning, Combined path planning and control.

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 4412: SOFT ROBOTICS [3 0 03]

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.

Introduction to Soft Robotics: [02]

Bio robotics, biomimetics, nature-inspired designs, materials for soft robot, biological analogy

Sensors and Actuators: [08]

Soft Actuators, Soft Sensors, Electroactive Polymer, Ionic Polymer Metal Composites, Shape Memory Alloy, Artificial Muscles based on Electric/Pneumatics, Thermal/Chemical Actuation

Rapid digital manufacturing of soft materials:**[10]**

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.

Modelling Soft Mechanics:**[13]**

Mathematical Modelling of Flexible Manipulator, Introduction to Euler Cauchy 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.

Applications:**[03]**

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 mechanics: 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 4413: 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: [03]

Introduction to Semiconductor devices, Device Basic Structure and Characteristics.

Diodes and MOSFETs: [10]

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: [08]

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: [10]

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: [05]

DC Characteristics, AC Characteristics, Processing overview.

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.

Self-study:

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

MTE 4414: 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: [05]

Introduction, structure, defects, bonds and bands, thermodynamics of material, kinetics, nucleation.

Thin film nucleation: [05]

Atomic view of substrate surfaces, thermodynamic aspects of Nucleation, Kinetic processes in Nucleation and growth.

Epitaxy: [06]

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: [10]

XRD, TEM, AFM, SEM.

Inter diffusion: [04]

Compound formation, phase transformation in thin film, metal, semiconductor reaction, mass transport in thin film.

Mechanical properties of thin films: [06]

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. Ephraim 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 4415: 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: [10]

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).

Chemical and Biological sensors: [06]

Chemical sensors, molecule-based biosensors, cell-based biosensors, transduction methods (Optical, Electrostatic, Electromagnetic, Capacitive, Piezoelectric, piezoresistive etc.),

Microactuators: [06]

Electromagnetic and Thermal microactuation, Mechanical design of microactuators, Microactuator examples,-microvalves, micropumps, micromotors , Microactuator systems : eg. Ink-Jet printer heads, Micro-mirror TV Projector

Introduction to interfacing methods: [06]

Bridge circuits, Programmable gain instrumentation amplifiers, A/D and D/A converters, microcontrollers

Applications and case studies: [08]

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, accelerometers, 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 4416: 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:

[10]

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:

[10]

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:

[10]

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, TunnelFETs.

Emerging research devices and architectures: [06]

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 4417: 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.

Agriculture for Engineers: [08]

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

Farm machinery: [12]

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.

Climate Controlled agriculture: [08]

Introduction, 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.

Harvesting Machinery: [04]

Working principles of harvesting machinery for various crops, Material handling equipment, conveyer and elevators, their working principle and selection

Post Harvesting Machinery: [04]

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 4418: 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.

Introduction to Robots: [02]

General robotic architecture, sensors, drive systems, kinematics, task and trajectory planning, robot controller and operating system.

Drive Systems: [10]

Classification and working of the electric and pneumatic drive used in robots, different types of pneumatic control valves and design of pneumatic control circuits.

Mechanical and soft grippers: [08]

working principles of different types of end-effectors, Design and development of robotic end-effector for harvesting different crops

Robotic Vision System: [08]

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.

Agriculture Drone: [08]

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, etc.

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 4419: 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.

Product quality and inspection:

[08]

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.

Product Quality Parameters and Measurements:

[06]

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.

Modelling and Prediction of Product Quality: [06]

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

Product Process Control: [06]

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.

Packaging Machinery and Systems: [10]

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.

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

Intelligent irrigation systems: [08]

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.

Precision Farming: [08]

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.

IOT and automatic farm: [08]

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.

Remote Sensing and Application: [06]

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.

ICT and Digital Tools: [06]

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.

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 4441: 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:**[08]**

Radiation mechanism and current distribution in thin wire antennas. Antenna fundamental parameters.

Radiation Integrals and Auxilliary Potential Functions:**[07]**

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:**[08]**

Circular loop antenna, antenna arrays, folded dipole, Helical antenna, Yagi – Uda array, log periodic antennas, Horn antenna, Microstrip antenna, Introduction to smart antennas, millimetre wave antenna and fractal antenna.

Introduction to RADAR and Navigation systems: [07]

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: [06]

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 4442: 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: [06]

Introduction - Augmented Reality, Virtual reality, Mixed Reality, Extended reality, The three I's of Virtual reality, History of Virtual reality, Early commercial VR Technology, Classic components of VR system.

Self Study: Perception, Temporal resolution, spatial resolution, motion perception, depth perception, color perception, auditory, perception, haptics perception

Displays in Augmented Reality: [10]

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

Self Study: Editor, Game objects and Components, materials, texturing, Basics lighting, skybox, Package import and export, modelling, scripting. Probuilder modelling, terrain creation, introduction to asset store, Avatar creation, Animator, Particle Systems, C# scripting

Computer Vision for Augmented Reality: [10]

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

Self Study: AR VR use cases: Industry 4.0, Blockchain, medical robotics, military and defence, automobile industry, Architecture Engineering, and Construction, Education, Manufacturing industry, Health care Industry.

Modelling: [10]

Geometric modelling, Kinematic modelling, Physical modelling, Behavioral modelling, Model management, Implementation using software tools, Application in human-robot interaction

Self Study: XR tool kit setup, Assembly smart factory, locomotion move turn, conveyor system animation, teleoperation, UI interaction

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 4443: 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: [07]

Introduction, Key issues for locomotion. Legged Mobile Robots, Leg configurations and stability, Examples of legged robot locomotion. Wheeled Mobile Robots, Wheeled locomotion: the design space, Wheeled locomotion: case studies.

Mobile Robot Kinematics and Motion in Global Coordinates: [07]

Kinematic Models and Constraints, Representing robot position, Forward kinematic models, Wheel kinematic, Robot kinematic constraints, Examples: robot kinematic models and constraints. Mobile Robot Maneuverability, Degree of mobility, Degree of steerability. Mobile Robot Workspace, Degrees of freedom, Holonomic robots. Motion control of mobile robots. Dynamics of Quadrotor-Type Mobile Robots.

Perception: [07]

Sensors for Mobile Robots, Sensor classification, characterizing sensor performance, Wheel/motor sensors, Heading sensors, Ground-based beacons, Active ranging, Motion/speed sensors, Vision-based sensors. Feature Extraction.

GNSS and Mobile Robot Localization: [08]

The Challenge of Localization: Noise and Aliasing. Localization-Based Navigation versus Programmed Solutions. Map Representation. Probabilistic Map-Based Localization. Global Navigation Satellite System: Position and velocity Calculation, GNSS Protocols.

Planning, Navigation and Energy Considerations: [07]

Competences for Navigation: Planning and Reacting, Path planning, Obstacle avoidance. 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 4444: 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: [05]

Introduction, physiological systems- biochemical, nervous, cardiovascular, respiratory, musculoskeletal systems, fusion of bio and mechatronics, biomechatronic system sensors, actuators, controller, signal processor, few application areas.

Sensors Technologies: [09]

Sensors for capture of biological signals- surface electromyographic sensors, intramuscular electromyography (EMG) sensors, electroencephalography (EEG) sensor, electrocardiography (ECG) sensor, electrooculography (EOG) sensor, types of electrodes, nerve cuff, brain array, oxygen light sensors, oxygen consumption sensors. Chemical sensors, electric sensors, optical sensors, mechanical sensors, thermal sensors.

Actuator Technologies: [07]

Purpose of Biomechatronic actuators- biological function replacement, augmentation, improvement, desirable characteristics, types of biomechatronic actuators-motors, electromagnetic actuators, fluidic actuators, shape memory alloys, electroactive polymers, transmissions- linear, rotary, differential gear transmissions.

Control of biomechatronic systems: [05]

Biomechatronic system model- Model based open loop control, model based closed loop control, case study-model based control of a biomechatronic system

Case studies:**[10]**

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.

MTE 4445: 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.

Introduction to Intelligent Buildings and Course overview.**[01]****Overview of Digital Controller:****[03]**

Data Form used in computers, Microcomputer, Input / Output Unit, Processor Operation and Software, Sensors, Actuator, I/O devices, Field Controllers.

Network and Communication protocols:**[06]**

Networking basics, Types of Networks-LAN, WAN, VLAN, Network topologies and their application area, Serial and Parallel Communication, RS232 and RS 485 Interfaces, Comparison between RS232 and RS485, MODBUS protocol overview, BACnet protocol overview.

Introduction to Building Management Systems:**[06]**

Quick Introduction to control systems, Brief about Building Automation, Buildings and Energy Management, Different systems in a building. Introduction to HVAC, StruxureWare for Building Operation Introduction, Features of SBO, Alarms, Trends, Schedules, Graphics, Menta Editor, Script Editor, Report Manager, S2Connect, Import/export, backup/Restore, webstation.

General BMS architecture: [02]
Traditional BAS architecture, SBO iBAS architecture (theory), BGRT BMS ROOM – site visit (practical)

Introduction to HVAC and Optimal control methods for HVAC Systems: [03]
Important components of HVAC, HVAC Control systems and Direct Digital Control, AHU, Chillers, Zones, Air Distribution Systems, Field Devices, Schneider Controllers (PLCs)

Lighting control systems: [02]
Purpose of lighting control system, Basic components of lighting control systems, Strategies for energy management and lighting control.

Security and Safety Control Systems: [06]
Access Control- Introduction, Basic Components, Controller / Panel, Credentials (Card, Finger Print etc...), Reader (with Keyboard to type pin), Locking Device, How it works / Operations, Type of Card/Readers, Anti-Pass back, Power Requirements, Videos (Digital Video Recorder), Types of Camera, How it works, Practical Demonstration (How to configure in a System). Fire Alarm Systems - Basic Components, Input device, Controller / Panel, Output devices, Detectors (Heat, Smoke, Fire Gas, Sprinklers)

System integration and convergence: [02]
Need for integration, interoperability and protocols, Compatibility of different open protocol standards, BMS integration case studies, iBMS, Compatibility of different internet technologies and its application in BMS,

Application of internet for Automation and Management: [01]
Web Based Automation, General Architecture, Web Enablement, Data Communication

Energy Management: [02]
Overview on EMS, Energy Analysis/Audit

Green Buildings (LEED): [02]
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, ISBN: 0387004459.

MTE 4446: 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: [05]

Cloud computing, Cloud computing delivery models and services, Ethical issues, Cloud vulnerabilities, Major challenges, Cloud computing at Amazon, The Google perspective, Microsoft Windows Azure, Open-source software platforms for private clouds, Cloud storage diversity and vendor lock-in, Energy use and ecological impact, Service level agreements, User experience and software licensing.

Application Paradigms: [05]

Challenges of cloud computing, Architectural styles of cloud computing, Workflows: Coordination of multiple activities, Coordination based on a state machine model: The Zookeeper, The Map Reduce programming model.

Cloud Resource Management and Scheduling: [06]

Policies and mechanisms for resource management, Feedback control based on dynamic thresholds, Coordination of specialized autonomic performance managers, Resourcing bundling: Combinatorial auctions for cloud resources, Scheduling algorithms for computing clouds, Fair queuing, Start-time fair queuing, Borrowed virtual time, Cloud scheduling subject to deadlines, Scheduling MapReduce applications subject to deadlines, Resource management and dynamic scaling.

Cloud Resource Virtualization: [11]

Virtualization, Layering and virtualization, Virtualization Overview, Virtualized Data Center (VDC) – Compute, Types of Virtualization, Understanding Hypervisors, Virtual Machine and its Components, Resource Management, Share, Limit and Reservation, Optimizing Memory Resource, Memory Ballooning, Virtual Machine Affinity, Physical to Virtual Conversion: Hot and Cold

Conversion Process, Virtualized Data Center (VDC) – Storage, Storage Virtualization at different Layers, Virtual Machine Storage Options and Considerations, Virtual Provisioning, Storage Tiering, Virtualized Data Center (VDC) – Networking, Components of VDC network infrastructure, Virtual Network Components, Virtual LAN, VLAN Trunking, VLAN Tagging, Network Traffic Management, Virtualized Data Center (VDC) - Desktop and Application, Performance comparison of virtual machines, The dark side of virtualization, Case Study: Xen, a VMM based par virtualization.

Cloud Security: [06]

Information Security, Basic Terminology, Cloud security risks, Security concerns and Threats, Privacy and privacy impact assessment, Trust, Operating system security, Virtual machine Security, Security of virtualization, Security risks posed by shared images, Security risks posed by a management OS, A trusted virtual machine monitor, Access Control and Identity Management in Cloud, Governance, Risk and Compliance, Virtualization Security Management, Trusted Cloud Computing

Cloud Tools: [03]

Overview of cloud software: Eucalyptus, Open Nebula/Open stack, CloudSim Framework: Modelling and simulating the cloud environment

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 4447: 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.

Data Analytics: [12]

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.

Machine Learning: [12]

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 Learning: [12]

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 4448: 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.

Statistical Data Mining Process: [11]

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: [09]

Feature Selection for Classification, Filter: Gini, Entropy and Fisher Score, Wrapper and Embedded Models, Decision Trees, Rules based classifiers, SVM: Linearly separable, Soft and Hard Margin and various kernel methods, Probabilistic Classifiers: Naïve Bayes and Neural Net with instance-based learning and classifier evaluation methods.

Mining Data Streams: [07]

Data Structures for Streams, Handling Concept Drift, Massive-Domain Scenario, Frequent Pattern Mining in Data Streams, Clustering Data Streams, STREAM Algorithm, CluStream Algorithm, Streaming Classification, VFDT Family.

Mining Data: [09]

Document Preparation and Similarity Computation, Specialized Clustering Methods for Text, Time-Series Preparation and Similarity, Time-Series Forecasting, Time-Series Clustering and Classification. Graph data methods, Web Crawling and Resource Discovery, Ranking Algorithms. Computer graphics, software tools, principles of figure tools.

References:

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

MTE 4449: 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 query 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: [04]

Types of production systems. Needs of digital manufacturing, effective & efficient use of digital manufacturing (DM) tools. Scope of digital manufacturing in future. Computers in manufacturing industries, Key challenges, techniques, requirements, product life cycle, Integration of CAD/CAM systems, Advantages of CAD/CAM systems.

Concurrent engineering: [06]

Definition & philosophy of concurrent engineering; teamwork; interfacing of manufacturing and design - design for manufacturability; project management; life cycle based on concurrent engineering; design for assembly. Examples – MEMS and 3D printing.

Industrial control systems: [04]

Process interfacing, collecting manufacturing process data, system interpretation of process data, interfacing hardware devices, and digital input/output processing, hierarchical computer structure and networking.

Computer networks in industries: [06]

Network technologies, LAN/MAN/WAN networks, Communications: Communication Methods, Direct numerical control, communication standards, communication protocols, design activity in a networked environment.

CIM and DBMS in manufacturing: [06]

CIM database, database requirements in CIM environment, database models – Hierarchical, network, RDBMS. Database architecture, SQL and coding.

Industrial ethics, technology and Engineering: [04]

SDL Introduction, The responsibility of engineers, Codes of conduct, normative ethics, the ethical cycle, Ethical questions in the design of technology, Designing morality, Ethical aspects of technological risks.

Digital twin and Blockchain technology in manufacturing: [06]

Digital twin for condition monitoring of 3D printer nozzle, block chain technology in food processing industries, development of digital thread to track the products.

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 4450: 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.

Visual Features: [08]

Image Formation, Linear Filtering, Correlation, and Convolution, Visual Features: Edge, Blobs, Corner Detection Algorithms, SIFT, SURF, HOG, Implementation using OpenCV Libraries.

Self study: Correlation, and Convolution

Deep Learning: [12]

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. Implementation using Deep Learning Libraries.

Self study: Comparison between various NN architectures

Object Recognition, and Segmentation:

[10]

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.

Self-study: Case study: Advanced driver assistance system (ADAS)

Generative Models in Vision:

[06]

Deep Generative Models: GAN, Cycle-GANs, Progressive GANs, StackGANs, Pix2Pix Applications: Image Editing, Inpainting, Super-Resolution, Image Restoration, 3D Object Generation, Implementation using Deep Learning Libraries.

Self-study: Case study: GAN for dataset generation (ADAS)

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 Mitchell, Tom. *Machine Learning*. New York, NY: McGraw-Hill, 1997

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

MTE 4451: 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.
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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.

Gears: [10]
 Bevel Gears - nomenclature, straight teeth bevel gears, cone angle, virtual number of teeth, face width, gear tooth force analysis, static strength, dynamic strength, wear strength. Worm Gears - nomenclature, materials, reversibility, mechanical advantage, gear tooth force analysis, strength design, efficiency, heat dissipation.

Sliding Contact Bearings: [05]
 Journal bearings, bearing modulus, Sommerfeld number, coefficient of friction, mechanism of film lubrication, eccentricity and minimum oil film thickness, temperature rise, oil flow, heat generation & dissipation.

Belt Drives: [03]
 Power transmission, flat and V- belts, ratio of belt tensions, centrifugal tension, power rating, V-flat drives, pulleys, selection of belts and pulleys.

Wire Rope Drives: [02]
 Types & construction of wire ropes, loads & stresses in ropes, selection of wire ropes.

Chain Drives: [02]
 Types of power chains, chordal action, sprocket size & teeth, chain speed, Selection of roller chains.

Mechanical Brakes: [06]
 Block brakes, Band brakes, Pivoted shoe brakes, disc brakes, torque capacity, heat dissipation.

Miscellaneous Topics: [08]
 Levers, seals, case studies involving field visit and making a design and report on the actual machineries.

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 Jersey, 2004.
4. Juvinile 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 4452: 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.

Introduction to Vehicle Technologies: [07]

History of Vehicle technology – Steam Powered Vehicles, Gasoline Powered Vehicles, Electric and Hybrid Vehicles. Case studies on vehicles – examples on gasoline, electric and hybrid vehicles. Economics aspects of vehicle technologies – Cost of vehicle, fuel cost and range of vehicles. Economics aspects of vehicle technologies – Air Pollution and GHG Emissions. Examine electricity production and emissions for Electric Vehicles.

Power Plants: [08]

Vehicle Dynamics – Resistive forces: Grading, Rolling, Aerodynamic and Acceleration. Tractive efforts and vehicle maximum speed. Power Plants in vehicle technologies. IC Engine based vehicles – Fundamentals and types. IC Engine speed torque characteristics. Ideal characteristics of vehicle. Essentials of Gears in IC Engine based vehicles. EV Power plant characteristics. Case studies on IC engine characteristics and EV Motor characteristics.

Electric Vehicle Components: [12]

Electric Vehicle components: Battery, Motors and Auxiliary units. Battery types in Electric Vehicles and functions. Motor types in Electric vehicles. Types of Electric Vehicle configurations – Conventional Electric vehicles with Multigear and clutch, Single Gear without clutch, integrated fixed gear, Multi motor fixed gear, Direct drive with fixed gear, In-wheel drive. Motors and their

control in EV propulsion. Concept of regenerative braking and its significance in Electric Vehicles. Control of Electric Vehicles. Challenges in Electric Vehicles.

Hybrid and Alternative Vehicles: [09]

Hybrid Vehicles – Significance of hybrid vehicles. Types: Series, Parallel, Series Parallel and Complex configurations. Power flow in Hybrid configurations. Concept of Hybridness – Mild, Pure, PHEV and range extension of vehicles. Control of Hybrid Vehicles. Fuel Cell based vehicles – Structure of Fuel cell, Zero Emission principle, Challenges in Fuel Cell based vehicles. Hydrogen generation. Solar energy for EV – fundamentals on solar energy, Onboard and off board solar power for EV.

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 4453: 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: [06]

Introduction to embedded system, major application areas of ES, design issues, performance metrics, characteristics and quality attributes of embedded systems, processor and memory organization, communication networks.

ARM: [18]

ARM processor introduction, MU0 processor, RISC design philosophy, The Acron RISC machine, architectural inheritance, programmer's model, developmental tools. ARM hardware and programming techniques: ARM assembly language programming: ARM instruction set, modes of operation, exception handlers, interrupts, programming examples. Pipelined architecture in ARM: 3- stage and 5- stage. THUMB instruction set: instruction format, conditional, branch, data processing, coprocessor instructions, implementation, and applications. memory mapped peripherals: UART and D/A converter. ARM cortex M3 architectural features and programming examples and case study.

RTOS: [12]

Concept of embedded operating systems, differences between traditional OS and RTOS, Introduction to real time OS, Tasks and Task states – semaphores – shared data – message queues, mail boxes and pipes – memory management – interrupt routines. Hard Real-Time systems, Soft Real-Time systems, real time scheduling considerations, Multicore real-time systems, Case studies on RTOS application domains.

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 4454: ENGINEERING MATERIALS [3 0 0 3]

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.

Introduction: [05]

Need, purpose, and importance of the subject. Crystal Structures(cubic and HCP structures) – computations – packing factor of cubic and HCP structure, co-ordination number, Miller indices, crystal imperfections-point& line defects.

Solidification Mechanisms and Phase diagrams: [10]

Homogeneous and heterogeneous nucleation. Mechanism of solidification –nucleation and crystal growth, dendritic growth, Solid solutions and types, Intermediate phases, Equilibrium diagrams(only binary), –construction and explanation of isomorphous and eutectic systems, equilibrium and non-equilibrium cooling, invariant reactions (eutectic, peritectic, monotectic, eutectoid, and peritectoid) Lever rule and its application on isomorphous and eutectic systems and Iron – iron carbide system.

Ferrous-alloys and Non-ferrous alloys: [05]

Principle and objectives of heat treatments Heat treatment of ferrous alloys, TTT diagram, annealing, normalizing, hardening, tempering and case hardening with heat treatment cycle, Composition, properties and applications of alloy steels. Types and explanation of brasses, bronzes and Al-Cu alloys and Lead tin alloys.

Polymers and Composites: [05]

Classification of polymers, degree of polymerization, thermoplastics and thermosets, adhesives. Dispersion strengthened composites particulate composites, fiber-reinforced composites and laminar composites.

Electronic, Magnetic and optical properties of materials: [11]

Conductivity of metals and alloys, deposition of thin films, insulators and dielectric properties, electrostriction, piezoelectricity and ferroelectricity, magnetic materials ,magnetization, magnetic field,ferro magnetic and super paramagnetic materials, application of magnetic materials. Refraction, reflection, transmission, selective absorption and use of 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 4455: 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.
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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: [12]

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: [12]

Review of basic concepts of complex analysis, Concepts of multivalued functions, branch points, branch cuts, Riemann surface and sheets, Fractional order 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: [12]

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 4456: 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

Foundations of HCI: **[06]**

The Human: I/O channels – Memory – Reasoning and problem solving; The Computer: Devices – Memory – processing and networks; Interaction: Models – frameworks – Ergonomics – styles – elements – interactivity- Paradigms. – Case Studies

Design and Software Process: **[06]**

Interactive Design: Basics – process – scenarios – navigation – screen design – Iteration and prototyping. HCI in software process: Software life cycle – usability engineering – Prototyping in practice – design rationale. Design rules: principles, standards, guidelines, rules. Evaluation Techniques – Universal Design

Models and Theories: **[06]**

HCI Models: Cognitive models: Socio-Organizational issues and stakeholder requirements – Communication and collaboration models-Hypertext, Multimedia.

Mobile HCI: **[06]**

Mobile Ecosystem: Platforms, Application frameworks- Types of Mobile Applications: Widgets, Applications, Games- Mobile Information Architecture, Mobile 2.0, Mobile Design: Elements of Mobile Design, Tools. – Case Studies

Web Interface Design: **[06]**

Designing Web Interfaces – Drag & Drop, Direct Selection, Contextual Tools, Overlays, Inlays and Virtual Pages, Process Flow – Case Studies

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 4457: 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: [02]

Introduction to Machine Learning, Supervised Learning, Unsupervised Learning, Mathematical Preliminaries: Review of Linear Algebra, Review of Probability theory, Overview of Convex optimization, Distributions, Statistical Evaluation Processes.

Probabilistic Models and Regression: [07]

Bayesian decision theory, Maximum likelihood method, Naïve Bayes, Regression, Multivariate methods. Application and

Supervised learning: [08]

Supervised learning: Logistic regression, Generative learning algorithms, Support vector machines, Model selection and feature selection, Evaluation and debugging learning algorithms. Perceptron.

Unsupervised learning: [08]

Clustering, K-means, Hierarchical clustering, Competitive learning, Dimensionality Reduction techniques. Application of unsupervised learning in anomaly detection and tactile manipulation.

Graphical models: [05]

Hidden Markov model, Belief Propagation. Application of graphical models.

Ensemble Machine learning: [05]

Generating diverse learners, Bagging, Boosting, Stacking. 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 Amel 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 4458: 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.

Introduction:

[10]

Elementary treatment of metal cutting theory, element of cutting process, Cutting Tools Classification, Nomenclature of single point cutting tool, geometry of single point tool angles, chip formation and types of chips, built up edge and its effects chip breakers, mechanics of orthogonal cutting, Forces acting on a tool, Merchant’s force diagram, Velocity relations, specific energy in cutting, cutting forces, cutting speeds, feed, depth of cut, Lathe tool Dynamometer.

Tool Wear:

[08]

Tool Wear, Tool life Factors affecting tool life, Taylor’s Tool life Equation, Tool wear mechanisms, Types of tool wear, Heat distribution in metal cutting, Measurement of temperature in metal cutting.

Cutting Tool Materials:

[06]

Requirements of tool materials, advances in tool materials, HSS, Coated HSS, Carbides ,Coated Carbides, Ceramics, Cold pressed, Hot Pressed , Ceramic Composites, CBN, Diamond- properties, Advantages and Limitations, Specifications for Inserts and tool holders

CNC Tooling: [06]

Turning tool geometry, Milling tooling systems, types of motion controls in CNC machines, Tool presetting, automated tool & pallet changing, work holding devices, cutting process parameter selection

Jigs and Fixtures: [06]

Principles of design of jigs and fixtures and uses, classification of jigs & fixtures, principles of location, Locating devices, 3-2-1 principle of location pin location: Radial location, ‘V’ location, Diamond locators, types of clamping & work holding devices, typical examples of jigs and fixtures.

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.
5. Juneja and Nitin Seth, *Fundamental of Metal Cutting and Machine Tools, (2e)*, New Age International Publishers, 2003.

MTE 4459: 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.

Image Acquisition and Analysis: [15]

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: Harris corners, SIFT, SURF, HOG.

Self-study: Comparison of Image enhancement algorithms

Motion Estimation and Tracking: [08]

Background subtraction, Lucas Kanade optical flow estimation, Object tracking using Kalman filter, Localization using passive markers.

Self-study: Sensor fusion, comparison of state-of-the-art video tracking algorithms (Critical review).

3D Vision: [08]

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.

Case Studies: [05]

Computer vision software tools for color and shape detection, Human detection, Object tracking, Camera calibration, Depth estimation, Stereo correspondence algorithms [05]

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 4460: 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.

Single Degree Freedom: [10]

Free and Damped Vibration Systems: Definition of Degrees of Freedom with Examples. Determination of Natural frequency by Newton's Classical method and Energy method. Longitudinal, Lateral and torsional systems. Damped free vibration: Viscous damping –Different types of Viscous damping.

Single degree systems with forced vibration with harmonic Excitation: [10]

Steady state forced vibration. Impressed excitation force due to rotating and reciprocation unbalance, Force Transmissibility and isolation. General theory of seismic instruments. Base excitation with harmonic input. Design of Accelerometer and Vibrometer.

Two degrees of freedom systems: [06]

Two degrees of freedom systems: Natural frequencies and mode shapes of vibration by classical method only. Forced vibration. Dynamic vibration absorber, Centrifugal pendulum absorber.

Multi-degree freedom systems: [10]

Multi-degree freedom systems. Influence co-efficient method. Iterative methods to determine natural frequencies: Holzer's method - Matrix iteration method. Rayleigh's and Dunkerley's methods for conservative lumped mass and distributed mass systems.

Self-study:

Case studies on vibrational experiments using different examples.

References:

1. Grover G.K., *Mechanical Vibrations*, Nemchand and Bros, Roorkee, 2012.
2. Singirisu Rao S, *Mechanical Vibration*, Pearson Education, Delhi, 2004.
3. Dukkappatti 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 4461: 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

Fundamentals of Electronic devices:

[06]

Intrinsic and extrinsic semiconductors- fermi level, conductivity, pn junction diodes, Zener diodes, Schottky diode, bipolar junction transistor (BJT), MOSFETs, optoelectronic devices- LEDs, photodetectors, solar cells.

Semiconductor Device Fabrication- Introduction and Operations:

[08]

Introduction to semiconductor manufacturing- Moore's Law, Scaling in CMOS, clean room concept, crystal structure of silicon, material properties, silicon wafer types, wafer slicing, basic wafer fabrication operations: layering-thermal oxidation, patterning, doping- thermal and ion implantation, heat treatment, example of a fabrication process.

Semiconductor Device Fabrication processes:

[16]

Lithography- photolithography, X-ray lithography, e-beam lithography, scanning probe, photoresists, masks; Etching- wet and dry; Deposition and growth- CVD, PVD, ALD, MBE; metallization- materials used, sputtering, CVD, electroplating; Polishing; process and device evaluation, process yield, IC fabrication examples; CMOS and SOI fabrication technology, SOI MOSFET, strained SiGe MOSFET.

Device Characterization and Packaging Techniques:

[06]

Two-point, four-point probes, capacitance voltage profiling, scanning electron microscopy (SEM), transmission electron microscopy (TEM), 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 4462: 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: [04]

Multidisciplinary nature of MEMS – principles and examples of Micro sensors and micro actuators – micro accelerometer –comb drives - Micro grippers – micro motors, micro valves, micro pumps, Shape Memory Alloys.

Review of Mechanical concepts: [04]

Stress, Strain, Modulus of 15% Elasticity, yield strength, ultimate strength – General stress strain relations – compliance matrix. Overview of commonly used mechanical structures in MEMS - Beams, Cantilevers, Plates, Diaphragms – Typical applications

Flexural beams: [02]

Types of Beams, longitudinal strain under pure bending – Deflection of beams –Spring constant of cantilever– Intrinsic stresses

Actuation and Sensing techniques: [04]

Thermal sensors and actuators, Electrostatic sensors and actuators, Piezoelectric sensors and actuators, magnetic actuators

Scaling laws in miniaturization: [03]

Scaling in geometry, scaling in rigid body dynamics, Trimmer force scaling vector, scaling in electrostatic and electromagnetic forces, scaling in electricity and fluidic dynamics, scaling in heat conducting and heat convection.

Materials for MEMS: [08]

Silicon – Silicon compounds – Silicon Nitride, Silicon Dioxide, Silicon carbide, Poly Silicon, GaAs, Silicon Piezo resistors, Polymers in MEMS – SU-8, PMMA, PDMS, Langmuir – Blodgett Films, Micro System fabrication – Photolithography – Ion implantation- Diffusion – Oxidation – Chemical vapour deposition – Etching.

Overview of Micro manufacturing: [03]

Bulk micro manufacturing, Surface micro machining, LIGA process –Micro stereo lithography

Micro system Packaging: [03]

General considerations in packaging design – Levels of Micro system packaging.

Bonding techniques for MEMS : [03]

Surface bonding , Anodic bonding , Silicon - on - Insulator , wire bonding , Sealing – Assembly of micro systems

Overview of MEMS areas: [02]

RF MEMS, BioMEMS, MOEMS, NEMS

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 4463: 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: [02]

Micro-manufacturing: An overview, Classifications of Micro-Manufacturing processes, Challenges in Meso, Micro, and Nanomanufacturing, Industrial applications and future scope of Micro-Manufacturing Processes.

Introduction to Traditional and Advanced Micromachining: [09]

Principles, working construction with applications of Microturning, Micromilling, Microgrinding, Biomachining, Micro- and Nano-manufacturing by Focused Ion Beam, Electric discharge micromachining, Electrochemical micromachining, Abrasive water jet micromachining.

Microcasting and Micromolding: [08]

Microcasting, Micromolding – A soft Lithography Technique, Fabrication of Microelectronic Devices

Microforming: [06]

Introduction to Microforming, Micro- and Nanostructured Surface Development by Nano Plastic Forming and Roller imprinting, Microextrusion, Microbending with Laser.

Microjoining: [05]

Introduction to Microjoining, Laser Microwelding, Electron Beams for Macro- and Microwelding working principle and construction with Applications.

Nanofinishing: [06]

Magnetorheological and Allied Finishing Processes and their theoretical analysis, Theoretical Analysis of Abrasive Flow Finishing (AFF) for Micromanufacturing, An Integrated Wafer Surface Evolution Model for Chemical Mechanical Planarization (CMP).

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., *Microfabrication & Nanomanufacturing*, CRC Press, 2005.

MTE 4464: 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: [10]

bottom-up and top-down approaches, physical and chemical properties, methods of preparation of nanoparticles, carbon nanostructures and their applications.

Physical chemistry of nanosystems: [08]

Micro electro mechanical devices and technologies - microsensors, MEMS fabrication processes and applications

Microscale and nanoscale heat conduction: [08]

Nanofluids preparation and characterization, nanomaterials used in energy and environmental applications and their properties

Future development of micro actuators: [10]

Nanolithography, 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 4465: 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: [06]

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 Objects: [04]

Classes and inheritance, Abstraction, Encapsulation, Polymorphism, Packages and interfaces.

In-built data structures in Python: [06]

Working with In-built data-structures, List, Tuples, Dictionaries and set and application involving abstract DS.

Exception handling, File handling and Event handling: [20]

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 4466: 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:

[02]

Introduction to production and operations management, Types of production activities- continuous, job order and custom work, Production consumption cycle discussion with example, Functions of production and operations management.

Forecasting:

[05]

Importance and uses of forecasting, Type of forecasts, Qualitative methods of forecasting - Historical estimate, Sale force estimate, Market Research and Delphi methods, Quantitative methods of forecasting – Simple and Weighted moving averages, Exponential smoothing, Linear regression analysis, Logarithmic straight line, Correlation analysis and Seasonality, Forecast control - Measures of forecast accuracy.

Product Development and Design:

[03]

Factors affecting product development and design, Product analysis, Economic analysis - Standardization, Simplification and Specialization, Preferred numbers, Product life cycle, Process design, Process Charts - Flow Diagrams and Man machine charts, Case study discussion on new product design and development.

Capacity Planning:

[05]

Introduction to capacity planning, Types of Capacity - Design capacity, System Capacity and System Efficiency, Factors affecting system capacity, Steps in capacity planning, Determination of equipment and manpower requirements, Decision tree analysis for capacity planning, Breakeven analysis in capacity planning, single and multi product P-V charts.

Aggregate Planning:

[03]

Pure and mixed strategies of aggregate planning, Trial and error approach, Use of transportation algorithm.

Job Shop Scheduling: [05]

Factors affecting job shop scheduling, Index method, Priority sequencing rules such as FCFS, SPT, EDD and Critical Ratio, Determination of mean flow time, average job lateness and average number of jobs in the system, Sequencing of “n” jobs through 2 machines, “n” jobs through 3 machines and 2 jobs through “n” machines.

Inventory management: [05]

Introduction, Classification of inventories, Economic order quantity, Inventory control models – EOQ determination with instantaneous delivery and finite delivery and with or without shortages, Effect of quantity discount, Safety stock, Reorder level, Lead time, ABC Analysis.

MRP: [02]

Introduction, Product structure tree, MRP inputs & outputs, MRP generation, Problems.

Line balancing: [03]

Meaning and determination of cycle time and theoretical minimum number of workstations, Precedence diagram, Priority rules for allocation of tasks to workstations, Longest work element time rule, Maximum following tasks rule - Calculation of efficiency and percentage delay loss, Real time case study discussion on industrial line balancing problems.

Location: [03]

Factors affecting location, Qualitative methods of location, Quantitative methods of location, Load distance method, Centre of gravity analysis, Plant layout, Types Factors affecting, use of load travel chart, Problems. SWOT analysis of deciding location for establishing new industrial setup.

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 4467: 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.
CLO 5	Modelling optimal policies for different tasks

Probability basic concepts: [04]

Probability, Random variables discrete and continuous, Conditional probability, Probability distributions, Bayes theorem, Maximum Likelihood

Sequential Decision Making with Evaluative Feedback: [04]

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: [04]

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: [04]

Value Functions, Rich Sutton and Andy Barto: A brief History of RL, Bellman Equation Derivation, Optimal Policies, Optimal Value Functions, Using Optimal Value Functions to Get Optimal Policies

Dynamic Programming: [03]

Iterative Policy Evaluation, Policy Improvement, Policy Iteration, Flexibility of the Policy Iteration Framework, Efficiency of Dynamic Programming

Monte Carlo Methods for Prediction & Control: [04]

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: [04]

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: [04]

Sarsa: GPI with TD, Sarsa in the Windy Grid World, Q-learning, Q-learning in the Windy Grid World, Q-learning off-policy. Expected Sarsa, Expected Sarsa in the Cliff World, Generality of Expected Sarsa.

Planning, Learning & Acting: [04]

Definition of a Model, Comparing Sample and Distribution Models, Random Tabular Q-planning, The Dyna Architecture, The Dyna Algorithm, Dyna & Q-learning in a Simple Maze, model 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 Bertsekas 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 4468: 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.

Introduction to Energy sources and generation: [05]

Energy resources and their utilization – Electrical energy generation from conventional sources. Indian power generation capacities from various sources. Energy Efficiency and conversion. Environmental aspects of Electrical Energy generation – Pollutions, Impact of Renewable Energy systems. Renewable energy economics for India.

Solar Energy Systems:**[11]**

Solar Energy – fundamentals of solar energy, Solar thermal conversion systems, Solar photovoltaics – cells, efficiency of solar cells, solar modules and sizing, solar photovoltaics systems, power electronics for solar energy systems. Solar photovoltaic applications. Grid connected PV systems. Case studies.

Wind Energy Systems:**[10]**

Wind Energy Systems – Fundamentals of wind energy systems, wind characteristics, wind energy conversion systems – turbines and generators. Grid connected and standalone wind power generation. Case studies.

Alternative Energy Sources:**[10]**

Small hydropower – fundamentals, classification, Major components of small hydropower plants. Geo-thermal fundamentals and power generation. Electric Power Generation by Ocean Energy – Fundamentals, Tidal Characteristics, Grid interfacing of tidal generation. Introduction to wave energy and conversion systems. Biomass Energy – Fundamentals and conversion systems. 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 4469: 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.

Introduction:

[06]

Concept of sustainability, manufacturing operations, resources in manufacturing. Concept of triple bottom line, environmental, economic and social dimensions of sustainability. Relation between green, lean and sustainable manufacturing.

Sustainability assessment methods:

[10]

Environmental conscious- quality function deployment-R3 and R6 cycles-Environmental impact assessment methods- CML, EI 95 and 99, ISO 14001, EMS and PAS 2050 standards, environmental impact parameters. Sustainability assessment-concept models and various approaches, product sustainability and risk assessment-corporate social responsibility.

Sustainable manufacturing processes:

[06]

Abrasive Jet Machining, Laser beam machining, Ultrasonic Machining, Electro Chemical Machining, Electro Discharge Machining.

Product Life cycle management and analysis:

[08]

Remanufacture and disposal, tools for LCA, optimization for achieving sustainability in manufacturing, value analysis, analysis for carbon footprint-software packages for sustainability analysis.

Case studies and SDL:

[06]

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 4470: 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.
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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.

Introduction: [06]

Principles of Modelling & Simulation, Classification of modelling: deterministic models its characterization and analysis, continuous time modelling, discrete time modelling, Modelling & Simulation of mixed systems, Transfer function; Block Diagram; State Space Representation (MIMO), limitations of modelling in control systems.

Dynamic Systems: [06]

Modelling of physical systems and their analysis: Electrical, Mechanical, Hydraulic, Acoustic Systems, Electromechanical, Thermal, Fluid, Mixed Systems, Mechanical systems, biological systems for Mechatronic Applications (Bond Graph Method).

Modelling Methods: [08]

1st Order Systems: Construction & Analysis with Practical Applications; 2nd Order Systems: Construction, Analysis; Practical Applications. Linear Systems: Methods of Model Order Determination, Impulse and Frequency Response Methods. Time Varying (Linear) Systems: Stability Concepts, Nonlinear Models: Introduction to Stable Oscillations, Chaotic Behaviour, Jump phenomena.

System Identification: [08]

Introduction to System Identification Bases, Algorithms for Parameter Estimation – Gradient Algorithm, Least Square Algorithm; Linear System: Identification Methods: Parametric Identification, Frequency Domain Identification; Least Squares Identification Methods; ARX, ARMAX Applications of LS and ARMA Methods, Regression Methods. Introduction to Non Linear Modelling, Identification: NARMAX Model

Case Studies: [08]

UAV Quad-rotor; Hard Discs; Maglev Systems, Ball & 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 4471: WIRELESS SENSOR NETWORKS [3 0 03]

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.

Introduction:

[05]

Challenges for wireless sensor networks, Comparison of wireless sensor networks with mobile ad hoc networks, Single node architecture – Hardware components, Energy consumption of sensor nodes, Network architecture – Sensor network scenarios: Types of sources and sinks, Single-hop versus multi-hop networks, Multiple sinks and sources, Gateway concepts: The need for gateways, WSN to internet communication, Internet to WSN communication, WSN tunneling, Wireless channel and communication fundamentals – Frequency allocation, Modulation and demodulation.

MAC Protocols in Sensor Networks:

[06]

Fundamentals of MAC protocols - Low duty cycle protocols and wakeup concepts - Contention-based protocols - Schedule-based protocols - SMAC - BMAC - Traffic-adaptive medium access protocol (TRAMA) - The IEEE 802.15.4 MAC protocol, Q-MAC (Query MAC), Q-MAC (QoS MAC).

Routing & Data Gathering Protocols:

[08]

Routing Challenges and Design Issues in Wireless Sensor Networks, Flooding and gossiping – Data centric Routing – SPIN – Directed Diffusion – Energy aware routing - Gradient-based routing - Rumor Routing – COUGAR – ACQUIRE – Hierarchical Routing - LEACH, PEGASIS – Location Based Routing – GF, GAF, GEAR, GPSR – Real Time routing Protocols – TEEN, APTEEN, SPEED, RAP - Data aggregation - data aggregation operations - Aggregate Queries in Sensor Networks - Aggregation Techniques – TAG, Tiny DB.

Transport Control Protocols and Middle wares for Wireless Sensor Networks:

[05]

Traditional Transport Control Protocols: TCP (RFC 793), UDP (RFC 768), MobileIP, Introduction, WSN Middleware Principles, Middleware Architecture: Existing Middleware: MiLAN (Middleware Linking Applications and Networks), IrisNet (Internet-Scale Resource-Intensive Sensor Networks Services).

Wireless Protocols & Interfaces: [06]

Wireless LANs: 802.11, 802.11a/b/g, 802.16-WiMAX, UWB Communications, Wireless Personal Area Networks, BlueTooth, BlueTooth Protocol Architecture, IEEE 802.15 standards, ZigBee, Wi-Fi.

Case Studies: [06]

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. Introduction to TinyOS – NesC, Interfaces, modules, configuration, Programming in TinyOS using NesC, Emulator TOSSIM.

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 4311: AUTONOMOUS MOBILE ROBOTS

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: [07]

Introduction, Key issues for locomotion, Legged Mobile Robots, Leg configurations and stability, Examples of legged robot locomotion, Wheeled Mobile Robots, Wheeled locomotion: the design space, Wheeled locomotion: case studies

Mobile Robot Kinematics: [07]

Kinematic Models and Constraints, Representing robot position, forward kinematic models, Wheel kinematic, Robot kinematic constraints, Examples: robot kinematic models and constraints, Mobile Robot Maneuverability, Degree of mobility, Degree of steerability, Robot maneuverability, Mobile Robot Workspace, Degrees of freedom, Holonomic robots.

Perception: [07]

Sensors for Mobile Robots, Sensor classification, characterizing sensor performance, Wheel/motor sensors, Heading sensors, Ground-based beacons, Active ranging, Motion/speed sensors, Vision-based sensors.

Mobile Robot Localization: [08]

The Challenge of Localization: Noise and Aliasing, Sensor noise, Sensor aliasing, Localization-Based Navigation versus Programmed Solutions, Map Representation, Continuous representations, Decomposition strategies, Probabilistic Map-Based Localization, Markov localization, Kalman filter localization.

Planning and Navigation: [07]

Competences for Navigation: Planning and Reacting, Path planning, Obstacle avoidance.

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 4312: FARM AUTOMATION [3 0 03]

At the end of the program 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.
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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.

Introduction: [08]

Farm automation system, components: 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: [08]

Types of irrigation Need for automated Irrigation, Portable timer system, Timer/Sensor Hybrid/SCADA, Methods of automating Irrigation layout, Machine Learning in Tank Monitoring System, Parameters for automated irrigation, IoT based Automated Irrigation System, Solar water pumping 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~~ (under IoT based Automated Irrigation), Cost and Benefits of Automation.

Automation in Protected Cultivation: [06]

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: [07]

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, Crop disease control using unmanned aerial vehicles (UAV)/drones.

Automation in food processing: [07]

Introduction, Post-Harvest and Food Processing Unit Operations, Material Handling, Packaging and Transportation, Novel Food processing techniques.

References:

1. Brian Wahlin and Darell Zimbelman, *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).
5. Choudhury, A., *Smart Agriculture Automation Using Advanced Technologies: Data Analytics and Machine Learning, Cloud Architecture, Automation and IoT*, (2021).

MTE 4313: 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.

Introduction to pneumatic systems:**[03]**

Advantages and limitations, 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:**[05]**

Various types of single acting and double acting cylinders, Types of 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, Fixed and variable type one and two way flow control valves, Dual pressure valve, shuttle valves, Time delay valves, Pressure sequence valves, pneumatic counter.

Manual pneumatics:**[02]**

Symbols of pneumatic valves, Traverse time diagram, Design of manually operated circuits, Direct and indirect control of actuators, Control of single and multiple actuators.

Electro-pneumatics and Design of electro pneumatic circuits: [12]

Electrically actuated direction control valves, Relay control systems, Limit switches, magnetic, inductive sensors, Capacitive, optical, ultrasonic, pneumatic proximity sensors, Symbols of electrical components, examples of circuits involving control of single acting cylinders, Examples of circuits involving control of double acting cylinders, Use of logics and sensors in applications. Design of pneumatic circuits using classic method, Cascade method and Step counter. Logic circuit design using K-V mapping and combinational circuit design

Introduction to Hydraulic systems: [03]

Advantages and limitations, Physical principles of oil hydraulics, Hydraulic power pack, Types of hydraulic pumps: Axial, Radial piston pump, Rotating cam radial type pump, gear pump, Vane pump, unbalanced vane type, Balanced vane pump, Pump specifications.

Hydraulic actuators, valves and accessories: [08]

Linear actuators, Rotary actuators, Accumulator: Weight loaded, spring loaded accumulators, Gas loaded accumulators, application of accumulators, Check valve, pilot operated check valve, Pressure control valves: Direct acting relief valve, Compound relief valve, Break valve, Sequence valve, Pressure reducing valve, Flow control valves: Simple restrictor flow control valve, Simple restrictor with reverse free flow check valve, Pressure compensated flow control valve and direction control valves.

Hydraulic circuits: [03]

Regenerative, meter in, meter out, bleed off, Sequencing, pressure reducing circuits, electro hydraulic 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 4314: 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 IIoT: [02]

Introduction to Industrial IoT, Components of IIoT.

Sensors and Actuators: [08]

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: [10]

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: [08]

AS-i, CAN, DeviceNet, Interbus, LON, Foundation Fieldbus, HART, PROFIBUS-PA, BACnet, ControlNet, IndustrialEthernet, Ethernet/IP, MODBUS, PROFIBUS-DP.

Database-System Applications: [03]

Purpose of Database Systems, View of Data, Database Languages, Relational Databases.

Introduction to security: [05]

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 4315: INTRODUCTION TO INDUSTRIAL ROBOTICS [3 0 0 3]

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

CLO1	Apply the fundamental knowledge gained by exploring the history, trends, and different associated factors of an industrial robot for the selection of its components.
CLO2	Analyze algebraic tools for the description of frame representation.
CLO3	Apply forward kinematics and inverse kinematics to compute position and joint variables respectively for given application.
CLO4	Develop robot dynamic equations considering necessary forces for different configurations of robots for given application.
CLO5	Select appropriate trajectory tracking planning by considering socio-economic and safety aspect of industrial robots.

Introduction: [05]
Definition of robots; Degrees of freedom; Degrees of movements, Robot configuration; definition and factor affecting the control resolution, Spatial resolution, Accuracy and repeatability, Specification of a robot, Actuators and sensors, Drives and transmission systems used in robotics.

Spatial Descriptions and Transformations: [05]
Descriptions- positions, Orientations and frames, Mappings-changing descriptions from frame to frame, Operators: translations, rotations, and transformations, Transform equations. Introduction to Lie algebra and Rodrigue's rotation formula and Quaternions.

Industrial Manipulator Kinematics: [10]
Introduction to kinematics, Link description, Convention for affixing frames to links, Manipulator kinematics, Actuator space, Joint space, and Cartesian space, Kinematics of industrial robots, Frames with standard names. Inverse kinematics of standard industrial manipulators: graphical, geometical and analytical approach.

Industrial Manipulator Dynamics: [06]
Introduction, Joint forces and torques, Jacobian and force vector, Joint velocities, Acceleration of a rigid body, Forward dynamics and inverse dynamic simulations in Robo Analyzer software.

Robotic Applications: [04]
Image processing: colour detection through Open CV programming. Arduino programming for servo and DC motor control

Socio-economic and Safety Aspect of Industrial Robots: [06]
Social and labor issues impact, assessment and future planning. Economic analysis for industrial robotics. Application of robots in industrial automation. Robotics technology of the future.

Self-Study:

Safety Aspect of Industrial Robots: Safety, training, maintenance and quality improvement in industrial robotics.

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.