2018 Syllabus: B. Tech. in MECHATRONICS ENGINEERING

Year	THIRD SEMESTER						FOURTH SEMESTER					
	Sub. Code	Subject Name	L	T	P	C	Sub. Code	Subject Name	L	T	P	C
II	MAT 2151	Engineering Mathematics – III	2	1	0	3	MAT 2261	Engineering Mathematics – IV	2	1	0	3
	MTE 2151	Data Structures and Algorithms	2	1	0	3	MTE 2251	Automated Manufacturing Systems	3	0	0	3
	MTE 2152	Digital System Design	3	1	0	4	MTE 2252	Design of Machine Elements	3	1	0	4
	MTE 2153	Microcontroller based System Design	4	0	0	4	MTE 2253	Linear Control Theory	3	1	0	4
	MTE 2154	Robotics I	2	1	0	3	MTE 2254	Linear Integrated Circuits and Applications.	3	1	0	4
	MTE 2155	Sensors and Instrumentation	4	0	0	4	*** ****	Open Elective – I				3
	MTE 2161	Microcontroller Lab	0	0	3	1	MTE 2261	CAD and Kinematics' Simulation Lab	0	0	3	1
	MTE 2162	Robotics Lab I	0	0	3	1	MTE 2262	Integrated Electronics Lab	0	0	3	1
	MTE 2163	Sensors and PLC lab	0	0	3	1	MTE 2263	Manufacturing Processes Lab	0	0	3	1
			17	**4**	**9**	**24**			**14**	**4**	**9**	**24**
	Total Contact Hours (L + T + P)		**30**				**Total Contact Hours (L + T + P) + OE**		**27 + 3 = 30**			
III	**FIFTH SEMESTER**						**SIXTH SEMESTER**					
	HUM 3051	Engg Economics and Financial Management	2	1	0	3	HUM 3052	Essentials of Management	2	1	0	3
	MTE 3151	Digital Signal Processing	3	1	0	4	MTE 3251	Automobile Engineering	2	1	0	3
	MTE 3152	Electric Drives	3	1	0	4	MTE 3252	Energy and Heat Transfer	3	1	0	4

	MTE 3153	Hydraulics and Pneumatics Systems	2	1	0	3	MTE 3253	Program Elective – I	3	0	0	3
	MTE 3154	Theory of Machines	3	1	0	4	MTE 3254	Program Elective – II	3	0	0	3
	*** ****	Open Elective – II				3	*** ****	Open Elective – III				3
	MTE 3161	Drives, Controls and Modelling Lab	0	0	6	2	MTE 3261	Hydraulics Lab	0	0	3	1
	MTE 3162	Robotics Lab II	0	0	3	1	MTE 3262	IIoT Lab	0	0	6	2
							MTE 3263	Pneumatics Lab	0	0	3	1
			13	**5**	**9**	**24**			**13**	**3**	**12**	**23**
	Total Contact Hours (L + T + P) + OE		**27 + 3 = 30**				**Total Contact Hours (L + T + P) + OE**		**28 + 3 = 31**			
IV	**SEVENTH SEMESTER**						**EIGHTH SEMESTER**					
	MTE ****	Program Elective – III	**3**	**0**	**0**	**3**	MTE 4298	Industrial Training				1
	MTE ****	Program Elective – IV	**3**	**0**	**0**	**3**	MTE 4299	Project Work/Practice School				12
	MTE ****	Program Elective – V	**3**	**0**	**0**	**3**	MTE 4296	Project Work (Only for B. Tech. Hons.)				20
	MTE ****	Program Elective – VI	**3**	**0**	**0**	**3**						
	MTE ****	Program Elective – VII	**3**	**0**	**0**	**3**						
	*** ****	Open Elective – IV				**3**						
			15	**0**	**0**	**18**						**13**
	Total Contact Hours (L + T + P) +OE		**15 + 3 = 18**									

Minor Specialization		
I. Electric Vehicle Technology MTE 4054: Vehicle Dynamics MTE 4072: Hybrid Vehicle Technology MTE 4084: Power Sources for Electric Vehicles MTE 4085: Modelling of Electric Vehicles **II. Industrial IoT Systems** MTE 4055: Database Management Systems MTE 4056: Information Security for Industrial Automation MTE 4057: Internetworking for Industries MTE 4058: Principles of Cryptography **III. Robotics and Automation** MTE 4059: Artificial Intelligence MTE 4060: Robot Dynamics and Control MTE 4061: Robot Path Planning and Mobile Robots MTE 4062: Soft Robotics **IV. Business Management** HUM 4051: Financial Management HUM 4052: Human Resource Management HUM 4053: Marketing Management HUM 4054: Operation Management	**V. Computational Mathematics** MAT 4051: Applied Statistics and Time Series Analysis MAT 4052: Computational Linear Algebra MAT 4053: Computational Probability and Design of Experiments MAT 4054: Graphs and Matrices **VI. Material Science** PHY 4015: Physics of Low Dimensional Materials PHY 4052: Physics of Photonic & Energy Storage Devices CHM 4051: Chemical Bonding CHM 4052: Chemistry of Carbon Compound **Other Electives** MTE 4051: Automotive Control Systems MTE 4052: Battery and Fuel Cell Technology MTE 4053: Mechatronics modelling of Hybrid Vehicles MTE 4063: Big Data Analytics MTE 4064: Building Automation MTE 4065: Computer Architecture and Real time Systems MTE 4066: Computer Networks and Communication Protocols MTE 4067: Design of Mechanical Drives MTE 4068: Dynamics and Controls of Mechatronics Systems MTE 4069: Electric Vehicle Machines and Drives MTE 4070: Embedded Systems and RTOS MTE 4071: Engineering Materials	MTE 4073: Machine Learning MTE 4074: Machine Tool Technology MTE 4075: Machine Vision and Image Processing MTE 4076: Mechanical Vibrations MTE 4077: Micro Electro Mechanical Systems MTE 4078: Micro-manufacturing Systems MTE 4079: Nanotechnology MTE 4080: Production Operations and Management MTE 4081: Robotics II MTE 4082: Systems Modelling and Simulation MTE 4083: Wireless Sensor Networks **Open Electives** MTE 4301: Autonomous Robots MTE 4302: Electric Vehicle Technology MTE 4303: Hydraulics and Pneumatics Systems MTE 4304: Industrial IoT MTE 4305: Introduction to Robotics MTE 4306: Mechatronics Systems

DETAILED SYLLABUSES FOR 2018 CURRICULUM

DEPARTMENT OF MECHATRONICS ENGINEERING

III SEMESTER

MAT 2151 ENGINEERING MATHEMATICS III [2 1 0 3]

Vector Calculus: **[11]**

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: **[09]**

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: **[07]**

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: **[09]**

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. Kreyszig, Erwin, *Advanced Engineering Mathematics*, John Wiley & Sons, (5e), 2010.
2. S. S. Sastry, *Introductory Methods of Numerical Analysis*, (2e), 1990, Prentice Hall.
3. B. S. Grewal, *Higher Engineering Mathematics*, 1989, Khanna Publishers
4. Murray R. Spiegel, *Vector Analysis*, 1959, Schaum Publishing Co.

MTE 2151 DATA STRUCTURES AND ALGORITHMS [2 1 0 3]

Pointer Arithmetic and Recursion: **[08]**

Accessing variables through pointers, Pointers arithmetic and arrays, Pointers and Functions, Recursion- definition, Recursive programs.

Programming using Data structures: **[07]**

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

Searching operations: **[07]**

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: **[07]**
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.

References:

1. Behrouz A. Forouzan, Richard F. Gilberg, *A Structured Programming Approach Using C*, (3e), Centage Learning India Pvt. Ltd. India, 2007.
2. Ellis Horowitz, Sartaj Sahni, Susan Anderson and Freed, *Fundamentals of Data Structures in C*, (2e), Silicon Press, 2007.
3. Richard F. Gillberg, Behrouz A. Forouzan, *Data Structures, A Pseudo code Approach with C*, (2e). Centage Learning India Pvt. Ltd. India, 2009.
4. Tenenbaum Aaron M., Langsam Yedidyah, Augenstein Moshe J., *Data Structures using C*, (1e), Pearson Prentice Hall of India Ltd., 2007.
5. Debasis Samanta, *Classic Data Structures*, (2e), PHI Learning Pvt. Ltd., India, 2010.

MTE 2152 DIGITAL SYSTEM DESIGN [3 1 0 4]

Combinational Logic Design: **[08]**

Minimization of Boolean functions using Karnaugh Map, Design of arithmetic circuits-Half adder, Full Adder, Half subtractor, Full Subtractor, Parallel Adder, Parallel Subtractor, Parallel adder cum subtractor, Parity generators and checkers, comparators. Design of Code converters. Design of display units, Multiplexers, De-multiplexers, Decoder, Encoder.

Synchronous Sequential Circuit Design: **[12]**

Need for sequential circuits, Binary cell, Latches and flip-flops. RS, JK, Master-Slave JK, D & T flip flops, Design of Synchronous and Asynchronous Counters, Shift registers & Ring counters, Design of Finite State Machines. Timing issues in synchronous circuits. Design examples such as elevator controls, traffic light controllers, vending machine.

FPGA Architectures: **[08]**

ACTEL, XILINX and ALTERA logic families, logic module, switching technology, I/O cells, Programmable interconnect.

Hardware Description Language: **[18]**

Introduction to HDL languages, Xilinx ISE tool. Logic design with Verilog HDL: Structural, dataflow and Behavioral models of combinational and sequential logic, hierarchical modeling, test benches, logic simulation using Xilinx toolset, coding examples.

References:

1. Morris Mano, "Digital design", (3e), Prentice Hall of India, 2002.
2. A. Anand Kumar, "Switching Theory and Logic Design", (2e), Prentice Hall of India, 2009.
3. Samir Palnitkar, "Verilog HDL: A Guide to Digital Design and Synthesis", 2nd Edition, Prentice Hall PTR, 2003.
4. David J Comer, "Digital Logic State Machine Design", 3rd Edition Oxford University Press, 2012.
5. Neil H.E Weste and Kamran Eshraghian, "Principles of CMOS VLSI Design", 2nd Edition, Addition Wesley, 1998.

MTE 2153 MICROCONTROLLER BASED SYSTEM DESIGN [4 0 0 4]

Introduction to Microcontroller based system design: [04]

Introduction to Microcomputer Based Digital Control, Significance and History of Microcomputer Technology, Basic function of Microcomputer Control, Selection of various Processor Architecture, Digital Vs Analog Control. Basics on Microcomputer Components, Microcomputer Architecture and Advanced Architecture

Microprocessor architecture and Instruction set: [04]

Microprocessor Architecture & Instruction Set, Memory & IO, Processor Technologies: Microcontroller, Digital Signal Processor

ARM Processor: [20]

RISC, Parallel Processors, Introduction to Advanced RISC Machines, History of ARM Microcontroller, ARM Architecture, programming model. Instruction set of ARM and Programming.

THUMB mode: [04]

THUMB mode: Programmers model. THUMB instruction set: Instruction format, THUMB Conditional, branch instruction, THUMB data processing instructions.

Programming ARM in C: [10]

Introduction to Programming ARM in C. Digital I/O – I/O ports programming using C, Interfacing of ARM. Coprocessor – architecture: Introduction to Arm cortex, M3 programmer model, stack and interrupts.

Case studies related to ARM: [06]

Case studies: ARM based system developments. Development of System: Hardware and Software Tradeoffs in design, Development Systems, Evaluation Boards , PC Based Add-On Cards , Advanced Workstation Based systems.

References:

1. Jonathan Valvano, *Embedded Systems: Real-Time Operating Systems for ARM Cortex-M*

Microcontrollers, Create Space Independent Publishing Platform, 2017
2. J.R.Gibson"*ARM Assembly Language-an Introduction*", Dept. of Electrical Engineering and Electronics, The University of Liverpool, 2007
3. Unsalan, Cem, H. Deniz Gurhan, and M. Erkin Yucel. *Programmable Microcontrollers: Applications on the MSP432 LaunchPad*. McGraw Hill Professional, 2017.
4. Bai, Ying. *Microcontroller Engineering with MSP432: Fundamentals and Applications*. Crc Press, 2016.

MTE 2154 ROBOTICS I [2 1 0 3]

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

Spatial descriptions and transformations: **[06]**

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.

Manipulator kinematics: **[06]**

Introduction to kinematics, link description, link-connection description, convention for affixing frames to links, manipulator kinematics, actuator space, joint space, and Cartesian space, kinematics of two industrial robots, frames with standard names. Introduction to kinematics of parallel manipulators, Close loop constraints, four bar mechanism, Stewart platform

Inverse manipulator kinematics: **[08]**

Solvability, notion of manipulator subspace, algebraic solution by reduction to polynomial, Pieper's solution when three axes intersect, examples of inverse manipulator kinematics, the standard frames, solving a manipulator, repeatability and accuracy.

Manipulator dynamics: **[05]**

Introduction, acceleration of a rigid body, mass distribution, Newton's equation, Euler's equation iterative Newton-Euler dynamic formulation, iterative vs. closed form, formulating manipulator dynamics in Cartesian space.

Trajectory generation: **[04]**

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

Linear control of manipulators: **[03]**

Introduction, feedback and closed-loop control, second-order linear systems, control of second-order systems, trajectory-following control, continuous vs. discrete time control, modeling and control of a single joint.

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.

MTE 2155 SENSORS AND INSTRUMENTATION [4 0 0 4]

Basic Measurement Concepts: [08]

Units and standards, calibration, static and dynamic characteristics of an instrument, error analysis, electromechanical indicating instruments.

Sensors and Transducers: [24]

Material science concepts: Materials used as sensors and transducers. Analog and digital voltmeters, ammeters, multimeters, DC bridges, AC bridges, fault detection- short circuit, open circuit, shielding and grounding methods, introduction to sensors and transducers, potentiometers, physical quantities and their measurements- strain, force, speed, velocity, acceleration, proximity and range, temperature, pressure, flow, level, O2 sensors, breathalyzers, display device- digital CRO, data storage.

Data Acquisition and PLC programming: [10]

Introduction to data acquisition, elements of data acquisition system, concept of signal conditioning. PLC: 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.

Communication: [06]

Industrial Process Automation, Networks and Protocols: AS-i, CAN, MODBUS, PROFIBUS-DP, Wi-Fi, Wi-MAX, Connectors.

References:

1. A.K. Sawhney, “A course in Electrical and Electronic Measurements and Instrumentation”, (19e), Dhanpat Rai & Co. Publishers, 2012.
2. A. K. Sawhney, “A course in Mechanical Measurement and Instrumentation”, (9e), Dhanpat Rai & Co. Publishers, 2012.

3. R.K. Rajput, “Electrical & Electronic Measurements & Instrumentation”, (2e), S.Chand Publishers, 2010.
4. Bela G. Liptak, “Process Measurement and Analysis”, (4e), CRC press, 2003.
5. Liptak, B.G. (Ed.), “Instrument engineers’ handbook, Vol. 3: Process software and digital networks”, (1e) CRC Press, Boca Raton, London, 2002.

MTE 2161 MICROCONTROLLER LAB [0 0 3 1]

Microcontroller: Introduction to ARM: Assembly and C programming, arithmetic instructions, array handling and code conversions, bit manipulations and logic instructions, timer/counter programming, serial communication and interrupts, interfacing ADC, interfacing DC and stepper motor, interfacing DAC, interfacing seven segment display, interfacing LCD, implementing a traffic light controller.

References:

1. Texas Instruments ARM Cortex M4 - MSP432 Reference Manual.
2. Texas Instruments Robotics System Learning Kit. http://www.ti.com/lit/ml/slay052a/slay052a.pdf
3. Code Composer Studio for Simplelink MSP432. http://www.ti.com/lit/ug/slau575k/slau575k.pdf
4. Bai, Ying. Microcontroller Engineering with MSP432: Fundamentals and Applications. Crc Press, 2016.

MTE 2162 ROBOTICS LAB I [0 0 3 1]

Robotics: Simulation of forward and inverse kinematics in computational software, Preliminary idea of master-slave control including hardware interfacing. Introduction to Robot Studio an offline Programming Tool. Defining Targets and Path Generation. Creating a Custom Tool and Defining a Work object. Conveyor Tracking using Robot Studio. Online programming using IRB2600 and Teachpendant, 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- Part Shape Detection using Sherlock –Image Processing Software. Food Quality Inspection. Colour Detection using Sherlock- Image Processing Software.

References:

1. John J. Craig, *Introduction to Robotics: Mechanics and Control*, (4e), Pearson, 2017.
2. Rafael Gonzalez, Richard Woods, *Digital Image processing*, (4e), Pearson, 2017.
3. Operating manual RobotStudio, ABB Robotics, 2021.
4. IRC5, Robotware 6.02, R15.2, User Documentation Rev C.

5. Sherlock Machine Vision Software User's Reference Manual, for Software versions 7.1.x and 7.2.x.
6. Universal Robots, Core training reference guide.
7. Universal Robots, Advanced training reference guide.

MTE 2163 SENSORICS AND PLC LAB [0 0 3 1]

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.

IV SEMESTER

MAT 2261 ENGINEERING MATHEMATICS IV [2 1 0 3]

Probability: **[11]**

Introduction, finite sample spaces, conditional probability and independence, Baye's theorem, one dimensional random variable, mean, variance. Two and higher dimensional random variables: mean, variance, correlation coefficient**.**

Distributions: **[11]**

Binomial, Poisson, uniform, normal, gamma, Chi-square and exponential distributions, simple problems. Moment generating function, Functions of one dimensional and two dimensional random variables, Sampling theory, Central limit theorem and applications.

Finite difference expressions for first and second order derivatives (ordinary and partial): **[07]**

Solution of boundary value problems, Numerical solutions of Laplace and Poisson equations by standard five point formula and heat and wave equations by explicit methods.

Difference equations: **[07]**

Difference equations representing physical systems, difference operator, the z transforms, properties of z transforms, initial and final value theorems, solution of difference equations by the method of z transforms.

Reference Books:

1. P. L. Meyer., *Introduction to Probability and Statistical Applications*, (2e), American Publishing Co., 1979.
2. Erwin Kreyszig, *Advanced Engineering Mathematics, (5e),* Wiley Eastern, 1985.
3. A. V. Openheim and R. W. Schafer , Digital Signal Processing, 1975, Prentice Hall
4. Hogg and Craig, *Introduction to Mathematical Statistics, (4e), MacMillan*, 1975
5. Narayanan, Ramaniah and Manicavachagom Pillay , *Advanced Engineering Mathematics, Vol 3.*

MTE 2251 AUTOMATED MANUFACTURING SYSTEMS [3 0 0 3]

Over View of Manufacturing and Automation: **[03]**

Production systems, Automation in production systems, Automation principles and strategies, Manufacturing operations, production facilities. Basic elements of an automated system, levels of automation.

Additive Manufacturing: **[08]**

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.

Subtractive Manufacturing: **[09]**

Computer Numerically controlled machining, Numerical control in Non-Traditional Machining: Abrasive Jet Machining, Ultrasonic Machining, Electro Chemical Machining, Electro Discharge Machining. Adoptive control Machining system. Basics of CNC programming (Simulation).

Flexible Manufacturing System: **[08]**

Group Technology, Cellular Manufacturing, Quantitative Analysis of Cellular Manufacturing (Rank order Clustering), Flexible Manufacturing system(FMS), Quantitative analysis of FMS (Bottleneck model), Computer Aided Process Planning (CAPP).

Product Life Cycle and Data Management (PLDM): **[08]**

Introduction to Product Life cycle Management(PLM), Need for PLM, opportunities and benefits of PLM, different views of PLM, components of PLM, phases of PLM, PLM feasibility study, PLM visioning. PLM Strategies: Industrial strategies, strategy elements, its identification, selection and implementation, make – to - stock, assemble-to order, make- to order strategy, change management for PLM, Strategies for recovery at end of life, recycling. Product Data Managment systems and importance, reason for implementing a PDM system, financial justification of PDM, barriers to PDM implementation.

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. Groover Mikell P, *Automation, Production Systems, and Computer Integrated manufacturing*, (4e), Prentice Hall of India. New Delhi, 2016.
4. Kalpakajain, *Manufacturing Engineering and Technology*, (4e), Addison Wesley, New York, 2014.
5. Saaksvuori, Antti, Immonen, Anselmi, *Product Lifecycle Management*, (2e), Springer-Verlag Berlin Heidelberg, 2005.

MTE 2252 DESIGN OF MACHINE ELEMENTS [3 1 0 4]

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.

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 2253 LINEAR CONTROL THEORY [3 1 0 4]

Introduction & mathematical modeling of physical systems: [10]

Introduction: Feedback control systems terminologies, types of system configuration, control system design process Modeling in frequency domain*:* Differential equation of physical systems(electrical, mechanical, electromechanical, systems with gears), Transfer function representation, State space representation of physical systems.

Time domain analysis and design: [12]

System characteristics: Introduction to 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 with and without disturbances, generalized error series.

Performance analysis: Stability, RH criteria, Root locus technique-construction and interpretation of system behavior

Frequency domain analysis : [12]

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

Compensator design and controllers: [14]

Effect of addition of poles and zeros on system response, introduction to compensator design and design of lag, lead, lag-lead compensating network (design via Root locus), Introduction to P, PI, PID controllers, Case studies.

References:

1. Norman S. Nise, *Control Systems Engineering*, (6e), Wiley India.
2. R.C Dorf, R. H. Bishop, *Modern Control Systems,* (8e), Wesley Longman Inc.
3. B.C. Kuo, F. Golnaraghi, *Automatic Control Systems*, (8e), Wiley India.
4. K. Ogata, *Modern Control Engineering*, (5e), PHI.

5. M. Gopal, *Control System: Principles and Practices*, (4e), TMH.

MTE 2254 LINEAR INTEGRATED CIRCUITS AND APPLICATIONS [3 1 0 4]

Introduction to Operational Amplifier (741 IC): [06]

Introduction to linear ICs & applications, Operational amplifier and block diagram representation, characteristics of ideal operational amplifier, Open loop and closed loop operation of operational amplifier, Inverting amplifier, non-inverting amplifier, input resistance, output resistance and band width.

OP-AMP Applications: [15]

Linear applications: The summing amplifier, difference amplifier, voltage follower, V-I converter, I-V converter, integrator, differentiator, instrumentation amplifier.
Non-linear applications: Precision rectifiers, peak detector, sample and hold circuit, Wave Shaping Circuits (Clipper and Clampers), log and antilog amplifiers, analog multipliers and dividers, comparators, Zero-crossing detector, window detector, Schmitt trigger.

Oscillators and waveform generators: [15]
Square wave, triangular wave form generators, pulse generator, ICL8038 function generator, The 555 timer, Barkhausen criterion, Wein Bridge and phase-shift oscillators, Phase Locked Loop-Operation of 565 PLL and its applications.

Active filters and Voltage Regulators: [06]

Design and analysis of first and higher order low pass, high pass, Band pass (wide and narrow band) and band elimination (wide and narrow band) and all pass active filters. Voltage Regulators -Need for Regulation-, Monolithic IC Regulators (78xx, 79xx, LM 317).

Data converters: [06]

Principles of digital to analog converter (DAC) and analog to digital converters (ADC), binary weighted, R-2R digital to analog converters, flash type, successive approximation type, counter type and servo tracking type and dual slope analog to digital converters, specifications of ADC and DAC.

References:

1. Stanley William D., *Operational Amplifiers with Linear Integrated Circuits*, Prentice Hall, 2004.
2. Franco Sergio, *Design with Op-amps and Analog Integrated Circuits*, McGraw Hill, (3e), 2002.
3. David L. Terrell and Butterworth – Heinemann, *Op Amps Design, Application, and Troubleshooting*, (2e), 1996.
4. Ramakant A. Gaikwad, *Op-Amps and Linear Integrated Circuits*, Prentice Hall of India, (4e), 2009.
5. Choudhury Roy D and Shail B. Jain, *Linear Integrated Circuits*, Wiley Eastern, (4e), 2011.

MTE 2261: CAD AND KINEMATICS' SIMULATION LAB [0 0 3 1]

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 etc... Kinematic analysis of simple mechanisms like slider crank mechanism, 4 bar mechanism, cam and follower mechanism.

References:

1. Gopalkrishna K. R., *Machine Drawing*, Subhas Publications, Bangalore, 2002.
2. Bhat N.D., *Machine Drawing*, Charotar Publishing House, Anand, 2002.
3. Venugopal K., *Engineering drawing and graphics + Auto CAD*, Newage International ublishers, Delhi 2002.
4. Narayana K.L. and Kannaiah P, *Text Book on Engineering drawing*, Scitech Publications, Chennai 2002.
5. Sham Tickoo, *CATIA – for Engineers and Designers*, Dreamtech Press, New Delhi 2005.

MTE 2262: INTEGRATED ELECTRONICS LAB [0 0 3 1]

Introduction to PSpice, Analog circuit designs using 741 IC linear applications of Op-amps, design of rectifiers, design of DACs and ADCs, design of filters, astable, monostable multivibrators& Schmitt trigger, using 555 IC design and study of astable and monostable multivibrators, using 78xx and LM 317 IC, design and study of regulators. Digital circuit designs- design of combinational circuits implementation of Boolean functions and arithmetic circuits, multiplexers, decoders, code converters, display driver interfaces, design of sequential circuits-design of ripple counters, shift registers and ring counters, design of synchronous counters, design of sequence detectors.

References:

1. Franco Sergio, *Design with Op amps & Analog Integrated Circuits*, McGraw Hill 1997.
2. J. Millman and H. Taub, *Pulse, Digital and Switching Waveforms*, TMH 2002.
3. Morris Mano, *Digital design*, (3e), Prentice Hall of India.
4. Ananda Kumar, *Switching Theory and Logic Design*, Prentice Hall of India, 2009.
5. Vladimirescu, *The PSpice Book*, J. Wiley & Sons, New York, 1994.

MTE 2263: MANUFACTURING PROCESS LAB [0 0 3 1]

Foundry shop: Introduction to molding and pattern materials; use of cores; exercises involving preparation of small sand mould and castings. Forging practice: Introduction to forging tools; exercises on simple smithy; metal cutting machine: preparing the turning models by using lathe; thread cutting; preparing models which includes milling, shaping and grinding (surface); spur gear cutting; CNC demonstration: vertical milling center and turning center.

References:

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

V SEMESTER

HUM 3051: ENGINEERING ECONOMICS AND FINANCIAL MANAGEMENT [2 1 0 3]

Nature and significance, Micro & macro differences, Law of demand and supply, Elasticity & equilibrium of demand & supply. Time value of money, Interest factors for discrete compounding, Nominal & effective interest rates, Present and future worth of single, Uniform gradient cash flow. Bases for comparison of alternatives, Present worth amount, Capitalized equivalent amount, Annual equivalent amount, Future worth amount, Capital recovery with return, Rate of return method, Incremental approach for economic analysis of alternatives, Replacement analysis. Break even analysis for single product and multi product firms, Break even analysis for evaluation of investment alternatives. Physical & functional depreciation, Straight line depreciation, Declining balance method of depreciation, Sum-of-the-years digits method of depreciation, Sinking fund and service output methods, Costing and its types – Job costing and Process costing, Introduction to balance sheet and profit & loss statement. Ratio analysis - Financial ratios such as liquidity ratios, Leverage ratios, Turn over ratios, and profitability ratios.

References:

1. Blank Leland T, Tarquin Anthony J. *Engineering Economy*, McGraw Hill, 2002.
2. Chan S. Park. *Contemporary Engineering Economics*, Pearson Education, Inc. 2010.
3. Raman B.S. *Advanced accountancy*, United publications, 1993.
4. T. Ramachandran. *Accounting and Financial Management*, Scitech Publications Pvt. Ltd., 2001.
5. Thuesen G.J & Thuesen H.G. *Engineering Economics*, Prentice Hall of India, 2005.

MTE 3151 DIGITAL SIGNAL PROCESSING [3 1 0 4]

Introduction to Signal Processing: **[14]**

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

Computation of DFT: **[06]**

Frequency Domain Analysis of Discrete Time Signals, Discrete Fourier Transform, Properties of DFT, Linear convolution using DFT. Fast Fourier Transform

Digital Filters: **[04]**

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

IIR Filter Design: **[10]**

Characteristics of IIR filters, Classical filter design using Butterworth and Chebyshev approximations, Impulse invariant and bilinear transformation methods, Frequency transformation technique for HP, BP and BS filter design, Direct design of IIR filters.

FIR Filter Design: **[08]**

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

Digital signal processors: **[03]**

Architectural features of digital signal processors, fixed point and floating point DSPs, DSP families, Case study of TMS320C24x processor.

Case study: **[03]**

Sensing, measurement and analysis of mechanical motion, fault analysis.

References:

1. Oppenheim A.V, Willsky A.S, *Signals and Systems*, (2e), PHI,2011
2. Oppenheim A.V. and R.W. Schafer, *Discrete time signal processing*, (2e), Prentice-Hall, 2001.
3. Proakis J.G. and D.G. Manolakis, *Digital Signal Processing: Principles, Algorithms and Applications*, (3e), PHI, 2007.
4. Rabiner L.R and Gold D.J, *Theory and Applications of Digital Signal Processing*, (2e), Prentice Hall, 2007.
5. *TMS320F/C24x DSP Controllers, Reference Guide*, June 1999.

MTE 3152 ELECTRIC DRIVES [3 1 0 4]

Introduction to Power Electronics: **[10]**

Power flow control switching, power electronic devices – power MOSFET and Power BJT , SCR – V-I , turn on, turn off characteristics, triggering methods, PWM methods, rectifiers – single phase – fully, half and semi controlled, half wave and full wave, full wave rectifier – RL loads, RLE loads with freewheeling diodes.

DC motors: **[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.

Induction Motors: **[15]**

Three phase motors, Principle of operation, Types of 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 concepts, solid state motor drivers –

ac voltage regulators, inverters - VSI, CSI. Single phase induction motors- types, torque speed characteristics, Synchronous motors.

Motors in automation: **[08]**

Linear Induction motors , PM Synchronous motors - Servo motors, Switched reluctance motors, BLDC motors, stepper motor – types , Universal motor, torque motor, - construction, torque- speed characteristics, applications, merits and demerits.

Fundamentals of Electric Drives: **[05]**

Basic Components of electric drive, Advantages of electric drives, Closed loop speed control, speed – torque conventions, multi-quadrant operation of electric drives, Steady state equilibrium, equivalent moment of inertia, Determination of motor power rating, Thermal ratings.

References:

1. Gopal K. Dubbey, *Fundamentals of Electric Drives*, (2e), Narosa Publishers, 2010.
2. Nagrath I.J. and Kothari D.P., *Electric machines*, (3e), Tata McGraw Hill, 2011.
3. Bimbra P.S., *Power electronics*, (3e), Khanna Publishers, 2010.
4. R. Krishnan, *Electric Motor Drives Modeling, Analysis, and Control*, (2e), Prentice Hall, 2012.

MTE 3153 HYDRAULICS AND PNEUMATICS SYSTEMS [2 1 0 3]

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 3154 THEORY OF MACHINES [3 1 0 4]

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, Number Synthesis, Grashof's criterion.

Analysis and synthesis of planar mechanisms: **[12]**

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, Advanced synthesis solutions, branch and order defects.

Balancing and Dynamic force analysis: **[10]**

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

Gears and Gear trains: **[12]**

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.

Lower Pairs: **[06]**

Straight line mechanisms, Steering Mechanism, Hooke's Joint. Real time case studies.

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 3161 DRIVES, CONTROLS AND MODELLING LAB [0 0 6 2]

Automation motors and their drivers and controls: Stepper motors, servo motors, linear motors etc.

References:

1. *Drives and Control training system- Practice module*, BOSCH REXROTH manual, Germany 2011.

MTE 3162 ROBOTICS LAB II [0 0 3 1]

Introduction to robot operating system- publisher , subscriber nodes, custom messages, robot motion with turtlesim, robot dynamic simulation in Gazebo and Rviz environments, implementation of robot model with URDF, simultaneous localization and mapping in ROS, introduction to ROS based system for path planning, implementation of model-based controller, integration of machine vision and robotics, basics of swarm robotics, simulation of soft robots, Intelligent control system for multibody system.

References:

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

VI SEMESTER

HUM 3052: ESSENTIALS OF MANAGEMENT [2 1 0 3]

Definition of management and systems approach, Nature & scope, The functions of managers, Corporate social responsibility. Planning: Types of plans, Steps in planning, Process of MBO, How to set objectives, Strategies, Policies & planning premises, Strategic planning process and tools. Nature & purpose of organising, Span of management, factors determining the span, Basic departmentalization, Line & staff concepts, Functional authority, Art of delegation, Decentralisation of authority. HR planning, Recruitment, Development and training. Theories of motivation, Special motivational techniques. Leadership - leadership behaviour & styles, Managerial grid. Basic Control Process, Critical Control Points & Standards, Budgets, Non-budgetary control devices. Profit & loss control, Control through ROI, Direct, Preventive control. Managerial practices in Japan & USA & application of Theory Z. The nature & purpose of international business & multinational corporations, unified global theory of management. Entrepreneurial traits, Creativity, Innovation management, Market analysis, Business plan concepts, Development of financial projections

References:

1. Koontz D. *Essentials of Management,* Mc Graw Hill, New York, 2004.
2. Peter Drucker. *Management, Task and Responsibility,* Allied Publishers, 2006.
3. Peter Drucker. *The practice of management,* Butterworth Hein Mann, 2003.

MTE 3251 AUTOMOBILE ENGINEERING [2 1 0 3]

Vehicle Body: **[05]**

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: **[04]**

Petrol, diesel, bio-diesel, electrical, hybrids, solar, wind, compressed air, fuel cell, hydrogen fuel cell-concept and working principle. Fuel supply and fuel monitoring system. Design aspects – BS4, B6 engine- difference – emission norms.

Transmission systems and tyres: **[10]**

Manual transmission-Sliding mesh gearbox, constant mesh gearbox, synchro mesh gearbox; automatic transmission- Overdrive(semi-automatic), Fluid drive; Fully automatic- Epicyclic gearbox, free wheeling unit, torque convertor. Clutch- friction clutches, electromagnetic clutches,

dual clutches, hydrodynamic clutches.; Meshing Orders of Drivetrain Systems, Noise and Vibration Characteristics of the Drivetrain System, differential – limit slip differential.

Automobile tyres – desirable properties, conventional tubed and tubeless tyre. Wheel wobble and wheel alignment. NVH in tyres- excitation characteristics.

Steering and suspension systems: [10]

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

Case study:- electric power steering system with torque feedback controller and Regenerative active suspension system with residual energy. -

Braking system: [03]

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: [04]

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

References:

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

MTE 3252 ENERGY AND HEAT TRANSFER [3 1 0 4]

Basic Concept of Work and Heat: **[10]**

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: **[07]**

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: **[09]**

Laminar flow though 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 though pipes in series and in parallel.

Heat Transfer- Introductory Concepts and Definitions: **[05]**

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: **[05]**

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**.**

References:

1. Cengel Y Al and Boles M A, *Thermodynamics, An Engineering Approach*, Tata Mc Graw Hill, 2003.
2. Michael J Moran, *Fundamentals of Engineering Thermodynamics*, Wiley India Pvt. Ltd., 2010.
3. Munson B R, Young D F and Okiishi T H, *Fundamentals of Fluid Mechanics*, John Wiley & Sons., Singapore, 2006
4. Kumar D. S, *Fluid Mechanics and Fluid Power Engineering*, Kataria S K and Sons, New Delhi, 2010.
5. Yunus A. Cengel, *Heat Transfer: A Practical Approach*, Tata McGraw Hill Inc., New Delhi, 2005.

MTE 3261 HYDRAULICS LAB [0 0 3 1]

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.

References:

1. *Industrial Hydraulics Trainee's manual*, BOSCH REXROTH manual, Germany 2011.

MTE 3262: IIOT LAB [0 0 6 2]

Operation of TwinCAT software, tools and usage. I/O accessing: Analog and Digital detection of sensors. Actuation on sensor detection using TwinCAT. HMI programming using TwinCAT. Operation of MSP432 microcontroller from TI. Interfacing of communication booster packs for Wi-Fi and Radio communication. Cloud access using BLYNK app. Interfacing the COBOT using Wi-FI. Remote access of 3D-Printer.

References:

1. *Beckhoff: New Automation Technology: Main Catalog, Volume 1, IPC, Motion, Automation,* Germany, 2018.
2. *Beckhoff: New Automation Technology: Main Catalog, Volume 2, I/O*, Germany, 2018.

MTE 3263: PNEUMATICS LAB [0 0 3 1]

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.

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.

MINOR SPECIALIZATIONS

I. Electric Vehicle Technology

MTE 4054: VEHICLE DYNAMICS [2 1 0 3]

Introduction: **[01]**

Introduction to Vehicle System Dynamics: Theoretical background on Vehicle Dynamics and control, Fundamental approach to Vehicle modelling.

Longitudinal Dynamics: **[08]**

Equation of Motion and Maximum Tractive Effort – Two axle vehicle, Tractor – Trailer Combination, Aerodynamic Forces and Moments, Acceleration Characteristics of a two – axle vehicle, Braking characteristics of a two – axle vehicle: Force Distribution, Braking Efficiency and Braking Distance, Braking Characteristics of Tractor – Semitrailer, Anti – lock Braking System, Traction Control System.

Tire Mechanics: **[08]**

Introduction, Mechanical Properties of Rubber, Tire Force and Moments, Contact Patch and Contact Pressure Distribution, Slip, Grip and Rolling Resistance. Cornering Properties of Tires – Slip Angle and Cornering Force, Slip Angle and Aligning Torques, Camber and Camber Thrust, Lateral Force Generation – Ply Steer and Conicity, Tire Models – Magic Formula, Brush Model, Performance of Tires on Wet Surfaces.

Lateral Dynamics: **[08]**

Introduction, Vehicle Axis System, Steering Geometry – Ackermann Steering Geometry. Steady State handling characteristics of a two - axis vehicle model: Bicycle Model, Stability, and Steering Conditions: Understeer, Neutral Steer, Oversteer. Steady – State Response to Steering Input – Yaw Velocity Response, Lateral Acceleration Response, Curvature Response. Testing of Handling Characteristics: Constant Speed Test, Constant Radius Test, Constant Steer Angle Test. Rollover: Quasi – Static rollover of a rigid vehicle, Quasi – Static rollover of a suspended vehicle. Rollover Prevention, Anti – Pitch Geometry, Anti – Squat Suspension Geometry.

Vertical Dynamics: **[03]**

Introduction, Quarter Car Model, Half Car Model.

Introduction to Automotive Safety: **[08]**

Basic concepts of vehicle safety, risk evaluation – the basic trilogy, decision models, accident avoidance, occupant injury prevention, human simulation applications, crash testing, special design models, future vehicle safety.

REFERENCES:

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

MTE 4072 HYBRID VEHICLE TECHNOLOGY [2 1 0 3]

Introduction to EV: [05]

History of Hybrid and Electric Vehicles technology, Economics and Environmental aspects of vehicle technologies, Need for Electric Mobility. Well to wheel analysis & comparison. EV Architectures, Case studies: Tesla Model S, Nissan Leaf, Ather 450, KPIT electric bus.

EV Configuration and Architecture: [04]

Components of Electric vehicles: Power train, energy source and auxiliary subsystems. EV Configurations. Performance of EV: Traction motor characteristics, Tractive effort, and transmission requirement.

Power Train: [10]

Power Train: Configuration and control of dc and induction motor drives for EV. PMSM, BLDC, SRM and SyncRel Motor drives for EV. Sizing of EV Motor, Peak Torque and Power, sizing of power Electronics devices and topologies.

Energy and Auxiliary Components of EV: [04]

Energy and energy management strategies, Regenerative braking-fundamentals. Auxiliary components technology in electric: steering unit, braking unit, HVAC unit, Auxiliary battery charging.

EV Controls: **[07]**

Control of Electric vehicles: Function of Control in EV and HEV, Elementary of Control theory, Electronic Control unit, Control Area Network, Control variables. Electric vehicle safety engineering, limitations of EV, Infrastructure, Overview of Testing.

Fundamentals of Hybrid: **[06]**

Fundamental concept of hybrid traction, hybrid drive train architecture – series, parallel torque, and speed coupling. Hybridness, Hybrid design philosophy, Mild, Micro, PHEV, Range extension 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 4084 POWER SOURCES FOR ELECTRIC VEHICLES [2 1 0 3]

Introduction: **[02]**

Batteries, Batteries in EV and HEV

Battery Basics: **[07]**

Battery Cell structure, Chemical Reactions, Battery Parameters: Battery capacity, Open circuit voltage, Terminal voltage, State of Charge, Discharge rate, State of discharge, Battery Energy, specific energy, Battery Power, Specific power. Types of batteries and their chemical reactions: Lead-acid and Lithium Batteries and their comparisons.

Lithium – Ion Technology: **[12]**

Development of Li-Ion Batteries in electric vehicles, Battery management technologies, BMS key technologies overview: Battery state estimation, Battery equalization, Battery safety management. Performance Modelling of Batteries. Electric Vehicle battery efficiency, Electric vehicle charging and fast charging, EV Battery discharging, EV Battery performance. Vehicle – to – Grid, Grid – to Vehicle.

Introduction to Alternative Energy device: **[06]**

Features of Supercapacitors, Basic principles of Supercapacitors, Performance of supercapacitors, Supercapacitors Technologies. Principles of Ultra-high-speed Flywheels, Flywheel technologies in EV and HEV. Hybridization of Energy storage devices. Passive and Active hybrid energy storage with battery and supercapacitors. Solar based Electric vehicles.

Fuel cells: **[09]**

Issues in Fuel Cells, Hydrogen Fuel cells, Types of Fuel Cells: Alkaline, Proton Exchange Membrane, Direct Methonal, Phosphoric Acid, Molten Carbonate, Solid Oxide. Fuel cell model. Cell efficiency and fuel cell voltage, Practical Fuel cell characteristics. Hydrogen storage systems, Fuel cell Hybrid Electric drivetrain.

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, Infrastructure, and the Market*, (1e), Elsevier, 2010.
4. Gianfranco Pistoia," *Behaviour of Lithium ion batteries in Electric Vehicles: Battery Health, Performance, Safety, Cost*", (1e), Springer, 2018.

MTE 4085: MODELLING OF ELECTRIC VEHICLES [2 1 0 3]

Electric Vehicle Propulsion and Powertrain **[05]**

Power Train Technologies: Rear Wheel, Front Wheel and Multi-wheel. Transmissions: Manual and Automatic. Drivetrain and Differential. Electric Power Train: BEV: Traction Motors, Energy Storage, PHEV, Fuel Cell based EV. Importance of Powertrain Modelling and Models – Drivetrain.

Modelling and Characteristics of Electric Propulsion System **[06]**

Electric Motor Performance Characteristics: Power and Torque Generation, Efficiency, DC Motors, Induction AC Motors, Steady-State Performance Analysis, Permanent-Magnet AC Motors. Modelling and Control of Electric Motors for EV: Power Converters, Motor Drives. Case studies.

Modelling and Analysis of Electric Vehicle Propulsion and Braking **[06]**

The Longitudinal Dynamics Equation of Motion, Vehicle Propulsion Modelling and Analysis: Electric Vehicles, Vehicle Braking Modelling and Analysis.

Control of Electric Vehicle Dynamics **[07]**

Fundamentals of Vehicle Dynamic Control (VDC) Systems, Driver, Vehicle, and Environment, Working Principle of VDC systems, VDC Systems Classification, VDC Implementation on Electric and Hybrid Vehicles, Structure of the Control System, Control System Design, Simulation Study.

Modelling of Power Sources for EV **[07]**

Modelling of Battery Systems: Battery Model, Charge/Discharge, Power Converter Topologies, Battery Control, Battery Management Systems, Battery Balancing Techniques for EV.

Design and Control of EV system: **[05]**

Motor Drive, Power Source, Power Topologies, Control, Performance of EV. Case Studies on EV, and Hybrid Electric Vehicles. Modelling and control of Fuel cell based EV.

References:

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

II. Industrial IoT Systems

MTE 4055 DATABASE MANGEMENT SYSTEMS [2 1 0 3]

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.

References:

1. Silberschatz, Korth, Sudarshan, *Database System Concepts*, (6e), McGrawHill, New York, 2011.
2. Ramez Elmasri and Shamkant Navathe, Durvasula V L N Somayajulu, Shyam K Gupta, *Fundamentals of Database Systems*, (6e), Pearson Education, United States of America,2011.
3. Thomas Connolly, Carolyn Begg, *Database Systems – A Practical Approach to Design, Implementation and Management*, (4e), Pearson Education, England, 2005.

4. Peter Rob, Carlos Coronel, *Database Systems–Design, Implementation and Management*, (10e), Course Technology, Boston , 2013.
5. Jiawei Han and Micheline Kamber, *Data Mining Concepts and Techniques*, Morgan Kauffmann Publishers, (2e), 2008

MTE 4056 INFORMATION SECURITY FOR INDUSTRIAL AUTOMATION [2 1 0 3]

Introduction to the principles of Security: **[06]**
Introduction to security, Characteristics of Information, Components of an Information system, Security System Development Lifecycle, The Need for Security- Business Needs first.

Threats and Attacks: **[06]**
Threats, Attacks, Intruders, Intrusion detection, Malicious Software – Types, Viruses, Viruses countermeasures, Worms.

Database security needs and principles: **[08]**
Introduction to Database security, SQL injection, Reliability and Integrity, Sensitive Data, Inference, Multilevel Databases, Proposals for Multilevel Security, Designs of Multilevel Secure Databases.

Web security principles: **[06]**
Transport-level Security- Web security issues, SSL, TLS, Pretty Good Privacy (PGP), S/MIME, IP security policy, Encapsulating Security payload, Internet Key Exchange.

Firewalls: **[04]**
The need for Firewalls, Firewall characteristics, Types of Firewalls

Cybercrimes: **[06]**
Cyber Crimes and Hackers- Cybercrimes, Cyber criminals, Hackers Hacking topologies, Types of Attacks, Dealing with the rising tide of cybercrimes, Indian Cyber Law offences.

References:

1. William Stallings, *Cryptography and Network Security: Principles and Practice*, (5e), Prentice Hall, 2010.
2. Michael E. Whitman and Herber J. Mattord, *Principles of Information Security*, (4e), Centage Learning India Publication, 2011.
3. Charles P Pfleeger and Shari Lawrence Pfleeger, *Security in Compution*,(4e), PHI, 2009.
4. Joseph Migga Kizza, *A Guide to Computer Network Security*, Springer Intertnation edition, 2009.

MTE 4057 INTERNETWORKING FOR INDUSTRIES [2 1 0 3]

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*, (1e) CRC Press, Boca Raton, London, 2002.
2. Andrew S. Tanenbaum, *Computer Networks*, (5e), Prentice Hall of India Pvt. Ltd., 2010.
3. William Stallings, *Data and Computer Communications*, (7e), Prentice Hall of India Pvt. Ltd., 2004.
4. James F. Kurose, Keith W. Ross, *Computer Networking (A Top-Down Approach Featuring the Internet)*, (3e), Pearson Education, 2005.

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

MTE 4058 PRINCIPLES OF CRYPTOGRAPHY [2 1 0 3]

Introduction to Cryptography: **[04]**

Introduction- Security goals, Attacks, Services and Mechanisms

Encryption techniques: **[10]**

Classical Encryption Techniques, Symmetric Cipher model, Transposition Techniques, The Data Encryption Standard, Block Cipher Operation, Multiple Encryption and Triple DES, Modes of operation

Mathematics of Cryptography: **[06]**
Mathematics of Cryptography- Modular Arithmetic, Fermat's and Euler's theorems, The Chinese Remainder Theorem

AES: **[06]**
AES- structure, Round Functions, Key Expansion, Pseudorandom Number generators, Stream ciphers, RC4.

Public Key Cryptography: **[05]**
Public-key Cryptosystems, RSA algorithm, Diffie-Hellman Key exchange, El Gamal Cryptosystem.

Hash functions: **[03]**
Cryptographic Hash functions- Applications, Hash functions based on Cipher Block Chaining, Secure Hash Algorithm.

Message authentication and Digital signatures: **[02]**
Message Authentication Function, Message Authentication codes, Digital Signatures.

References:

1. William Stallings, *Cryptography and Network Security: Principles and Practice*, (5e), Prentice Hall, 2010.
2. Behrouz A. Forouzan and Debdeep Mukhopadhyay, *Cryptography and Network Security*, (2e), McGraw Hill, 2008.
3. Atul Kahate, *Cryptography and Network Security*, Tata McGraw-Hill Publishing, 2008.
4. Bruce Schneier, *Applied Cryptography*, (2e), John Wiley and Sons, Inc., 1996.

III. Robotics and Automation

MTE 4059 ARTIFICIAL INTELLIGENCE [2 1 0 3]

Fundamentals: **[04]**
Fundamentals of Artificial Neural Networks, McCulloch – Pitts model, Activation functions, Feed forward and feedback networks, learning rules – Hebbian, Perceptron, delta, Widrow-Hoff, winner take all.

Single layer feed forward networks: **[04]**
Introduction, Perceptron Models: Discrete, Continuous and Multi-Category, Training Algorithms: Discrete and Continuous Perceptron Networks, Perceptron Convergence theorem, Limitations of the Perceptron Model, Applications.

Multi-layer feed forward networks: **[08]**
Generalized Delta Rule, Derivation of Back propagation (BP) Training, Summary of Back propagation Algorithm, Kolmogorov Theorem, Learning Difficulties and Improvements.

Application of neural networks: Control applications, Character recognition

Fuzzy control: **[04]**
Introduction to Fuzzy control, classical sets & fuzzy sets, fuzzy set operations, Fuzzy relations, membership function, extension principles. Linguistic variables, Fuzzy IF_THEN statements, Inference rules.

Fuzzy Logic System Components: **[08]**
Fuzzification, Membership Value assignment, development of rule base and decision making system, Defuzzification to crisp sets, Defuzzification methods. **Application of fuzzy logic:** control applications. (Case study)

Introduction to Genetic Algorithm (GA): **[04]**
Principles**,** working operation**,** Design**,** Applications in control system.

Introduction of hybrid system: **[04]**
Fuzzy-neural systems (options neuro-fuzzy, neuro-genetic and fuzzy genetics), Familiarization with MATLAB Fuzzy logic & neural network Toolbox.

References:

1. Jacek M. Zurada, *Introduction to artificial neural networks*, Jaico, 2006.
2. Timothy J. Ross, *Fuzzy logic with engineering applications*, MGH, 2010.
3. Chin-Teng-Lin, C. S. George Lee, *Neural fuzzy systems*, PHI, 1996.
4. Rajasekharan and Rai, *Neural networks, fuzzy logic, genetic algorithms: synthesis and applications*, PHI Publication, 2017

MTE 4060 ROBOT DYNAMICS AND CONTROL [2 1 0 3]

Review of Robot Kinematics: **[09]**

Examples of Robotic Systems, Transformations: Joint/Task space, Forward Kinematics, Inverse Kinematics, Jacobians, Trajectory Generation, Serial and Parallel Kinematics

Robot Dynamics: **[09]**

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: **[09]**

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. Inverse dynamics controllers, Force control, stiffness control, Impedance control, Hybrid Position/Force Control, Reduced state modeling and control, Impedance Control, Stiffness and Compliance, Under-actuated System

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 4061 ROBOT PATH PLANNING AND MOBILE ROBOTS [2 0 3 3]

Autonomous mobile robots: **[05]**

Introduction, locomotion - key issues for locomotion, legged mobile robots, leg configurations & stability, examples of legged robot locomotion, wheeled mobile robots. Wheeled locomotion-the design space. Robot kinematics models & constraints, Mobile robot maneuverability- degree of mobility, Degree of steer ability, Robot maneuverability. Mobile robot workspace-degree of freedom, Homonymic 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.

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 Decompostion: **[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.

List of Experiments:

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

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 4062 SOFT ROBOTICS [2 1 0 3]

INTRODUCTION TO SOFT ROBOTICS- MOTIVATION: **[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 MULTIFUNCTIONAL 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.

MODELING SOFT MECHANICS (NUMERICAL, COMPUTATIONAL, ANALYTICAL): **[13]**

Mathematical Modelling of Flexible Manipulator, Introduction to Euler Cautchy Elasticity Problem Hyper-redundant kinematic structures, Resolution of inverse kinematics, Mathematical formulation for animating flexible structure, Bio-mimetics (modelling of snake/earthworm, caterpillar etc), Continuum Mechanics, Eigenvalues and Eigenvectors, Geometric interpretation of

eigenvectors, Cayley-Hamilton theorem, Principal Component Analysis, Singular Value Decomposition, ISO-Map Dimensional Reduction technique.

APPLICATIONS: **[03]**
Case Studies on wearable Robotics, Space Robotics, Deep-Sea Robotics, Healthcare Systems, Under-actuated Robots

References:

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

OTHER ELECTIVES

MTE 4051 AUTOMOTIVE CONTROL SYSTEMS [2 1 0 3]

Introduction to Automotive Control Systems: **[05]**
Overview of Automotive Control Systems, Automotive Control-System Design Process, Identifying the Control Requirements

Engine operations: **[04]**
Review of Engine Modeling, Engine Operations, Engine Control Loops, Control-Oriented Engine Modeling

Vehicle Dynamics: **[06]**
Vehicle Dynamics, Coordinates and Notation for Vehicle Dynamics, Longitudinal Vehicle Motion, Lateral Vehicle Motion, Vertical Vehicle Motion.

Vehicle Automation basics: **[05]**
Human Factors in Vehicle Automation, Driver Modeling, Design, Modeling, and Control of Automotive Transmission Systems, Powertrain Control Systems, Air–Fuel Ratio Control, Control of Spark Timing, Idle-Speed Control, Transmission Control

Hybrid Vehicles: **[07]**
Design, Modeling, and Control of Hybrid Systems: Control of Hybrid Vehicles, Series, Parallel, and Split Hybrid Configurations, Hybrid Vehicle-Control Hierarchy, Control Concepts for Series

Hybrids, Control Concepts for Parallel Hybrids, Control Concept for Split Hybrids, Feedback-Based Supervisory Controller for PHEVs.

Fuel-cells modelling: **[02]**

Modeling and Control of Fuel Cells for Vehicles: Modeling of Fuel-Cell Systems, Control of Fuel-Cell Systems, Control of Fuel-Cell Vehicles.

Other design considerations: **[07]**

Parametric Design Considerations, Cruise and Headway Control, Antilock Brake and Traction-Control Systems, Vehicle Stability Control, Four-Wheel Steering, Active Suspensions, Overview of Intelligent Transportation Systems, Preventing Collisions, Longitudinal Motion Control and Platoons, Automated Steering and Lateral Control.

References:

1. Zong Xuan, *Automotive propulsion systems*, CRC press, 2015.
2. A. Galip Ulsoy, Ann Arbor, *Automotive Control Systems*, Cambridge university press, 2012.
3. M. Thoma, F. Allgöwer, M. Morari, *Identification for automotive systems*, Springer, 2012.
4. B.T. Fijalkowski, *Automotive Mechatronics: Operational and Practical Issues*, Springer, 2011.

MTE 4052: BATTERY AND FUEL CELL TECHNOLOGY [2 1 0 3]

Introduction: **[02]**

Batteries, Batteries in EV and HEV

Battery Basics: **[07]**

Battery Cell structure, Chemical Reactions, Battery Parameters: Battery capacity, Open circuit voltage, Terminal voltage, State of Charge, Discharge rate, State of discharge, Battery Energy, specific energy, Battery Power, Specific power. Types of batteries and their chemical reactions: Lead-acid and Lithium Batteries and their comparisons.

Lithium – Ion Technology: **[14]**

Development of Li-Ion Batteries in electric vehicles, Battery management technologies, BMS key technologies overview: Battery state estimation, Battery equalization, Battery safety management. Performance Modelling of Batteries. Electric Vehicle battery efficiency, Electric vehicle charging and fast charging, EV Battery discharging, EV Battery performance. Vehicle – to – Grid, Grid – to Vehicle.

Introduction to Alternative Energy device: **[06]**

Features of Supercapacitors, Basic principles of Supercapacitors, Performance of supercapacitors, Supercapacitors Technologies. Principles of Ultra-high-speed Flywheels, Flywheel technologies in EV and HEV. Hybridization of Energy storage devices. Passive and Active hybrid energy storage with battery and supercapacitors.

Fuel cells: **[07]**

Issues in Fuel Cells, Hydrogen Fuel cells, Types of Fuel Cells: Alkaline, Proton Exchange Membrane, Direct Methonal, Phosphoric Acid, Molten Carbonate, Solid Oxide. Fuel cell model. Cell efficiency and fuel cell voltage, Practical Fuel cell characteristics. Hydrogen storage systems, Fuel cell Hybrid Electric drivetrain.

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, Infrastructure, and the Market*, (1e), Elsevier, 2010.
4. Gianfranco Pistoia," *Behaviour of Lithium ion batteries in Electric Vehicles: Battery Health, Performance, Safety, Cost*", (1e), Springer, 2018.

MTE 4053: MECHATRONICS MODELLING OF HYBRID VEHICLES [2 1 0 3]

Introduction to Vehicle Propulsion and Powertrain Technologies: Objectives of vehicle propulsion control. Powertrain architecture and technologies. Importance of Powertrain Modeling and Models – Drivetrain. Engine Management systems (EMS): Basic engine operation- EMS building block, Effective work, Engine control structure and components, Automatic Code Generation and Information Exchange - Calibration and Parameter Representation - Engine Maps - Model-Based Development. Fuel management and control: Stoichiometry and air-fuel ratio – Engine concepts and its geometry, Engine control – Power, torque and mean effective pressure - Feed-forward and Feedback Control Structure, Fuel Dynamics and Injector Compensation Driveline modeling Driveline control: General Modeling Methodology - Graphical Scheme of a Driveline - A Basic Complete Model and Rigid Driveline - Reflected Mass and Inertias - Modeling of Neutral Gear and Open Clutch -Torque Converter - Control Design and Validating Simulations- Driveline control – goals of driveline control – State-space formulation – Controller formulation – Driveline control with LQG/LTR. Miscellaneous -Vehicle control systems and performance measures: ABS control systems –ABS cycle detection – control of the Yaw dynamics – derivation of simplified control law – derivation of reference values

References:

1. Lars Eriksson, Lars Nielsen, *Modeling and Control of Engines and Drivelines*, (1e), Wiley, 2014.
2. Georg Rill, *Road Vehicle Dynamics: Fundamentals and Modeling*, CRC press- Taylor and Francis group, 2011.

3. Uwe Kiencke, Lars Nielsen**,** *Automotive Control Systems: For Engine, Driveline and Vehicle*, (2e), Springer, 2005.
4. Rolf Isermann, *Engine Modeling and Control: Modeling and Electronic Management of Internal Combustion Engines*, Springer, 2014.

MTE 4063 BIG DATA ANALYTICS [2 1 0 3]

Introduction to Big Data Analytics: [05]

Big Data, Characteristics of Big Data, Data in a warehouse and data in Hadoop, Importance of Big Data, Big data use cases, Meet Hadoop.

Distributed file systems and Map Reduce: [11]

Map Reduce, Distributed File System, Algorithms using Map Reduce. Communication Cost model, Complexity Theory, Comparison with other systems

Introduction to Hadoop: [11]

The Hadoop Distributed File System, Hadoop I/O, File Based Data structures, Developing a Map Reduce Application

Case studies and Applications: [09]

Inverted Index for Text Retrieval, Graph Algorithms, Page Rank, Stream Data Model: A Datastream Management system, Sampling Data in a Stream, Filtering Streams, Distinct Elements in a Stream, NOSQL Models, Understanding Storage Architecture, Performing CURD operations, Querying NOSQL Stores.

References:

1. Anand Rajaraman and Jeffrey David Ullman, *Mining of Massive Datasets*, (1e) Cambridge University Press, 2011.
2. Tom White, *Hadoop: The definitive guide*, (3e), O'reilly, Yahoo Press, 2012.
3. Shashank Tiwari, *Professional NOSQL*, (2e), Wiley India Pvt. Ltd., 2012.
4. Jimmy Line, Chris Dyer, *Data Intensive Text Processing with MapReducee*, (1e), Mprgan and Claypool Publishers, 2010.
5. Paul C Zikopoulous, Chris Eaton, Dirk Deroos, Thomas Deutch, George Lapis, *Understanding Big Data*, (1e) McGraw Hill, 2012.

MTE 4064 BUILDING AUTOMATION [2 1 0 3]

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 4065 COMPUTER ARCHITECTURE AND REAL TIME SYSTEMS [2 1 0 3]

Introduction to Computer Architecture: **[04]**
Organization and Architecture, Processor Organization

Concept of Parallelism: **[08]**
The Instruction Cycle, Introduction to Parallel processing, Parallel Computer Structures, Architectural Classification schemes, Pipelining, Instruction Level Parallelism, SIMD Computer Organizations, SIMD Interconnection networks, Parallel Algorithms for Array processors,

Multiprocessor functioning: **[06]**
Symmetric Multiprocessor Organization, Cache Coherence and the MESI protocol, Multithreading and Chip Multiprocessors, Synchronization, Models of Memory Consistency,

Clustered architecture: **[06]**
Clusters, Operation System Design Issues, Cluster Computer Architecture, Blade servers, Clusters compared to SMP, Multicore computers

Performance issues: **[08]**
Hardware Performance issues: Increase in Parallelism, Power consumption, Software performance issues: Software on multicore, Multicore organization

Intel x86 Multicore organization: **[04]**
Intel Core Duo, Intel Core i7.

References:

1. William Stalling, *Computer Organization and Architecture: Designing for Performance*, (8e), Pearson Prentice Hall, 2010.
2. Kai Hwan and Faye A. Briggs, *Computer Architecture and Parallel Processing*, TMH Private Ltd., 2012.
3. John L. Hennessy and David A. Patterson, *Computer Architecture, A Quantitative Approach*, (5e), Morgan Kaufmann, 2014.

4. Rajiv Chopra, *Advanced Computer Architecture (A Practical Approach)*, S. Chand and Company Ltd. 2011.

MTE 4066 COMPUTER NETWORKS AND COMMUNICATION PROTOCOLS [3 0 0 3]

Introduction to Reference Models: [04]
Introduction to data communication, Network architecture, Basics of OSI and TCP/IP reference models.

Transmission Media: [07]
Wired and wireless connectivity, FDM, TDM and CDMA, Circuit and packet switching. Frame relay and ATM switching, ISDN, Local area network protocols, IEEE standards for LAN, Satellite networks.

Data link layer design issues: [04]
Its functions and protocols, link layer: error detection and correction techniques, Multiple access protocol, Ethernet, hubs and switches , PPP.

Network layer: [12]
Protocol and Packet format: Internet protocol, IPv6, Routing algorithms, IP addressing schemes, Internetworking and sub-netting. Transport layer: connectionless transport-UDP, principles of reliable data transfer, congestion control algorithm. Application layer design issues: FTP, Electronic Mail in the Internet, P2P file sharing, HTTP.

Quality of Services: [05]
ATM, Differentiated services Model, Flow identification, Scheduling, Factors affecting QOS parameters and service categories. QOS classes, [5]

Network Management: [04]
Network Management protocol, SNMP, CMIP, Issues in the management of large networks, Concept of Traffic and service. Voice and video data, ATM Traffic, Elements of ATM Traffic management-Traffic contracting.

References:

1. James F. Kurose, Keith W. Ross, *Computer Networking (A Top-Down Approach Featuring the Internet, (3/e)*, Pearson Education, 2005.
2. Andrew S. Tanenbaum, *Computer Networks*, (5e), PHI, 2010.
3. Charle Kaufman, Radia Perlman, Mike Specines, Uyless Black, *Computer Networks: Protocols Standards and Interfaces,* Prentice Hall of India Pvt. Ltd. 2010.
4. William Stallings, *Data and Computer Communications*, (7e), 2004, Prentice Hall of India Pvt. Ltd.

MTE 4067 DESIGN OF MECHANICAL DRIVES [2 1 0 3]

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.

References:

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

MTE 4068 DYNAMICS AND CONTROL OF MECHATRONICS SYSTEMS [3 0 0 3]

Industrial Feedback controllers: **[06]**

Performance indices, PID controllers, tuning – Ziegler – Nicholas Tuning Methods, Design of PID controllers – Frequency Response Approach, Computational optimization, Modified PID scheme, Two degrees of freedom control, Zero placement Approach.

Introduction to State Space Analysis: **[10]**

State space representations - Canonical form, observable forms, diagonal form , Jordan form, Eigen vectors and Eigen values, invariance of Eigen values, state space formulation of transfer functions, state space modeling of physical systems - inverted pendulum, ball and beam system, cruise control, armature controlled DC motor, vehicle suspension system (linear systems)

Control System Design in state space: **[10]**

Solution of LTI state equation, Controllability and Observability, Pole placement methods, state feedback controllers, methods to determine gain matrix K, state observers - full order, methods to determine observer gain matrix Ke, Design of regulator systems with observers (2^{nd} order systems). Lyapunov stability analysis, Linear quadratic optimal control– inverted pendulum, suspension systems- case study.

Non – Linear Systems: **[06]**

Types of nonlinearity - dead zone, saturation, hysteresis, jump resonance, backlash. Describing functions - saturation, dead zone, phase plane method, linearization techniques – Taylor series expansion, feedback linearization techniques – upto 2^{nd} order systems. Case study – Nonlinear modeling of cruise control- linearization.

Matlab and Simulink: **[04]**

Matlab based examples of state space modeling, feedback controllers, observers, regulator problems.

References:

1. Ogata K., *Modern Control Engineering*, (5e), Pearson Prentice Hall, 2005.
2. Karl J. Astrom, *Feedback systems- An Introduction for Scientists and Engineers*, Princeton University Press, 2008.
3. Norman S. Nise, *Control Systems Engineering, (6e)*, John Wiley & Sons, Inc, 2011.
4. Stanley M. Shinners, *Modern Control Systems, Theory and Design*, John Wiley & Sons, Inc, 2009.
5. Gopal M., *Modern Control System Theory*, (*2e)*, New Age International Ltd, 2005.

MTE 4069 ELECTRIC VEHICLE MACHINES AND DRIVES [3 0 0 3]

Overview of EV Technologies: **[05]**
Motor Drive Technology, Energy Source Technology, Battery Charging Technology, Vehicle-to-Grid Technology, Pure Electric Vehicle, Hybrid Electric Vehicle, Gridable Hybrid Electric Vehicle, Fuel-Cell Electric Vehicle.

DC Motor Drives: **[05]**
System Configurations, DC Machines, DC–DC Converters, Soft-Switching DC–DC Converter Topologies, DC Motor Control, Regenerative Braking, Design Criteria of DC Motor Drives for EVs, Design Example for EVs.

Induction Motor Drives: **[04]**
System Configurations, induction Machines, Inverters for Induction Motors, Induction Motor Control, Design Criteria of Induction Motor Drives for EVs, Application Examples of Induction Motor Drives in EVs

Permanent Magnet Brushless Motor Drives: **[06]**
System Configurations, PM Brushless Machines, PM Brushless Motor Control, Design Criteria of PM Brushless Motor Drives for EVs, Design Examples of PM Brushless Motor Drives for EVs, Planetary-Geared PM Synchronous Motor Drive, Outer-Rotor PM Brushless DC Motor Drive, Application Examples of PM Brushless Motor Drives in EVs

Switched Reluctance Motor Drives: **[06]**
SRM Machines, SR Converters, Comparison of SR Converters for EVs, SR Motor Control, Design Criteria of SR Motor Drives for EVs, Machine Initialization, Planetary-Geared SR Motor Drive, Outer-Rotor In-Wheel SR Motor Drive, Application Examples of SR Motor Drives in EVs , Stator-Permanent Magnet Motor Drives

Integrated-Starter-Generator Systems: **[04]**
System Configurations, ISG Machines, ISG Operations, Cranking, Electricity Generation, Idle Stop-Start ,Power Assistance, Design Criteria of ISG Systems 300 10.6 Design Examples of ISG Systems 301

Planetary-Geared Electric Variable Transmission Systems: **[03]**
Input-Split PG EVT Systems, Compound-Split PG EVT Systems, Design Criteria of PG EVT Systems, PM Synchronous PG EVT System Configuration, Application Examples of PG EVT Systems in HEVs

Double-Rotor Electric Variable Transmission Systems: **[03]**
Double-Rotor Machines, Basic Double-Rotor EVT Systems, Advanced Double-Rotor EVT Systems, Axial-Flux DR EVT System, Magnetless DR EVT System, Design Criteria of DR EVT Systems, Design Example of DR EVT Systems, Potential Applications of DR EVT Systems in HEVs

References:

1. K T Chau, *Electric Vehicle Machines and Drives- Design, Analysis and Application*, (1e) John Wiley & Sons, 2015.

MTE 4070 EMBEDDED SYSTEMS AND RTOS [2 1 0 3]

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.

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 4071 ENGINEERING MATERIALS [3 0 0 3]

Introduction: **[5]**

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 (euctectic, 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: **[5]**
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: **[5]**
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 supper 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 4073 MACHINE LEARNING [2103]

Introduction: **[2]**
Introduction to Machine Learning, Supervised Learning, Unsupervised Learning, Mathematical Preliminaries: Review of Linear Algebra, Review of Probability theory, Overview of Convex optimization, Hidden Markov models, Multivariate Gaussian distribution, Gaussian Processes.

Classification and regression: **[7]**
Bayesian decision theory, Maximum likelihood ratio, Parametric classification, Regression, Multivariate methods, K-nearest neighbor classification. Application of classification and regression in imitation learning for Robot Grasping.

Supervised learning: **[8]**

Supervised learning: Setup, LMS, Logistic regression, Perceptron, Exponential family, Generative learning algorithms, Gaussian discriminant analysis, Naïve Bayes, Support vector machines, Model selection and feature selection, Evaluation and debugging learning algorithms. Application of supervised learning: Watch-Bot.

Unsupervised learning: **[8]**

Clustering, K-means, Hierarchical clustering, Competitive learning, Radial basis functions. EM, Mixture of Gaussians, Factor analysis, Principal Component Analysis, Independent Component Analysis. Application of unsupervised learning in anomaly detection and tactile manipulation.

Graphical models: **[5]**

Naïve Bayes classifier, Hidden Markov model, Linear Regression, Belief Propagation. Application of graphical models : DeVAR (Desktop Vocational Assistant Robot).

Combining multiple learners and applications of machine learning: **[5]**

Generating diverse learners, Voting, Error correction output codes, Bagging, Boosting. Applications of Machine learning in Robotics: Developmental Robotics, Cognitive Robotics, Evolutionary Robotics.

References:

1. Kevin P. Murphy, *Machine Learning: A Probabilistic Perspective*, (1e), MIT Press, 2012.
2. Ethem Alpaydin, *Introduction to Machine Learning*, (2e), MIT Press, 2010.
3. Mehryar Mohri, Afshin Rostamizadeh and Amet Talwalkar, *Foundation of Machine Learning*, (1e), MIT Press 2012.
4. Daphne Koller and Nir Friedman, *Probabilistic Graphical Models: Principles and Techniques*, (1e), MIT Press, 2009.
5. Christopher M. Bishop, *Pattern Recognition and Machine Learning*, (1e), Springer, 2007.

MTE 4074 MACHINE TOOL TECHNOLOGY [3 0 0 3]

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

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 4075 MACHINE VISION AND IMAGE PROCESSING [2 1 0 3]

Image Acquisition and Analysis: **[15]**

Vision system components, Image acquisition and analysis, Image formation - Sampling & Quantization, simple operations on image, Image enhancement: Spatial Domain and frequency domain methods, Image noise, image restoration , morphological operations, Segmentation, image analysis, representation of regions, Feature extraction, fundamentals of color image processing, conversion of color spaces.

3D Vision: **[08]**

Camera modeling, Introduction to strobbing light, RGB+D camera, Time of flight(ToF) cameras, Perspective Projection Geometry, Rotation and translation, Pinhole camera model, 2D and 3D Geometrical Transformations, Calibration methods, Intrinsic and Extrinsic Camera Parameters, Location Determination Problem(LDP), Stereovision**,** Stereo correspondence Algorithms – Feature Based and Correlation Based, Epipolar Geometry, Rotational Matrix, Fundamental Matrix, 3D Reconstruction

Motion Estimation and Tracking: **[05]**

Optical flow estimation, Object tracking with Kalman filtering, Basic idea of localization employing passive markers , Basic concepts of sensors fusion, Integration of vision data with IMU unit

Case Studies/Application: **[08]**

Basic color detection: Comparative analysis using different color models, Face recognition, Vehicle tracking, applications using computer vision toolbox and image processing toolbox.

References:

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

MTE 4076 MECHANICAL VIBRATIONS [2 1 0 3]

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 excitiation with hormonic 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.

References:

1. Grover G.K., *Mechanical Vibrations,* Nemchand and Bros, Roorkee, 2012.
2. Singirisu Rao S, *Mechanical Vibration,* Pearson Education, Delhi, 2004.
3. Dukkapatti Rao V., *Text Book of Mechanical Vibration*. Prentice Hall of India Ltd, 2004.
4. Daniel Imnan J. *Engineering Vibration*, Prentice Hall, New Delhi, 2001.

5. Thomson W.T., *Theory of Vibrations with Applications,* Chapman and Hall, 4th Edition, 1993.

MTE 4077 MICRO ELECTRO MECHANICAL SYSTEMS [2 1 0 3]

Introduction to MEMS and Microsystems: [02]

Products, Evolution of micro-fabrication, microelectronics, miniaturization, application in the automotive and other industries.

Working principles of Microsystems: [05]

Microsensors – Acoustic wave sensors, Bio-medical sensors and bio sensors, Chemical sensors, Optical sensors, Pressure sensors, Thermal sensors. Microactuation – By thermal forces, Shape memory alloys, piezoelectric crystals and Electrostatic forces, MEMS with Micro actuators, Micro accelerometers, Microfluidics, Problems

Scaling laws in miniaturization: [04]

Scaling in geometry, Scaling in rigid body dynamics, Scaling in electrostatic, electromagnetic forces, Scaling in electricity, Scaling in heat transfer and fluid mechanics

Materials for MEMS and microsystems: [05]

Substrates and wafers, Silicon as a substrate material, silicon compounds, silicon piezo-resistors, Gallium arsenide, Quartz, Polymers, Packaging materials, Problems.

Microsystems fabrication Processes: [06]

Photo lithography, Ion implantation, Diffusion, Oxidation, Chemical vapor deposition, Physical vapor deposition, Deposition by Epitaxy, Etching, Problems.

Micro-manufacturing: [05]

Bulk manufacturing, Surface micromachining, LIGA process.

Microsystems Design: [05]

Design consideration, Process design, Mechanical design, Design of a silicon die, Design of microfluidic Network system. Problems.

Microsystems Packaging: [04]

Mechanical packaging of microelectronics, Microsystems packaging, Interfaces in microsystems packaging, packaging technologies, 3 Dimensional packaging, Assembly of microsystems, Packaging materials, Signal mapping and transduction.

References:

1. Tai Ran Hsu, *MEMS and Microsystems - Design and Manufacturing*, Tata McGraw Hill, 2010.
2. Marc J. Madou, *Fundamentals of Micro Fabrication - The Science of Miniaturization*, CRC Press, 2002.

3. Wolfgang Menz, J. Mohr and Oliver Paul, *Microsystem Technology*, Wiley-VCH, 2001.
4. Mohamed Gad-el-Hak, *The MEMS Handbook*, CRC Press 2002.
5. S.D. Senturia, *Microsystem Design*, Kluwer Academic Publishers, 2001.

MTE 4078 MICRO - MANUFACTURING SYSTEMS [3 0 0 3]

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

MTE 4079 NANOTECHNOLOGY [3 0 0 3]

Fundamentals of Nanotechnology: **[04]**

Processing system of nanometer accuracies-mechanism of material processing-Nano Physical processing of atomic bit-units-Nano-chemical and electrochemical atomic-bit processing

Nano-Measuring Systems of Sub-Nanometer Accuracy and Resolution: **[08]**

In process or in situ measurement of position of processing point-Post process and on machine measurement of dimensional features and surface-mechanical measuring systems -optical measuring systems-Electron beam measuring systems-pattern recognition and inspection systems.

Nano-Positioning System of Nanometer Accuracy and Repeatability: **[08]**

Guide systems for moving elements-servo control systems for tool positioning-computer aided digital ultra-precision position control-Future development of micro actuators.

Applications of Nanotechnology: **[12]**

Nano-grating system-Nano-lithography-Photolithography-electron beam lithography machining of soft metal mirrors with diamond turning-mirror grinding of ceramics-ultra-precision block gauges, balls for rolling bearings-fabrication CCD's, VCR head assemblies, Optical fibers.

Future Trends in Nanotechnology: **[04]**

Development of intelligent products-Nanoprocessing of materials for super high density IC's-nanomechanical parts-Micromachines.

References:

1. Charles P. Poole, *Introduction to Nanotechnology*, Wiley-Interscience, 2003.
2. Guozhong Cao, *Nanostructures & Nanomaterials*, Imperial College Press, 2004.
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 4080 PRODUCTION AND OPERATIONS MANAGEMENT [2 1 0 3]

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.

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.

MTE 4081 ROBOTICS II [2 1 0 3]

Autonomous mobile robots: **[07]**

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

Robot control problems: **[07]**

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: **[06]**

Lyapunov stability theorem, Robust control, Feedback-Linearization Controllers, Lyapunov Designs, Variable-Structure Controllers , Saturation-Type Controllers. Inverse dynamics controllers, Force control, stiffness control, Impedance control, Hybrid Position/Force Control, Reduced state modeling and control

Modeling soft mechanics (numerical, computational, analytical): **[08]**

Hyper-redundant kinematic structures, Resolution of inverse kinematics, Mathematical formulation for animating flexible structure, Bio-mimitics(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.

Sensors and Actuators: **[08]**

Soft Actuators (dielectrics, pneumatics, fluidics),Soft Sensors(fluidic, solid, composites, textiles) ,Electroactive Polymer, Ionic Polymer Metal Composites, Shape Memory Alloy, Artificial Muscles based on Electric/Pneumatics, Thermal/Chemical Actuation

References:

1. Jog, C.S., *Foundations and applications of mechanics: Volume I: Continuum mechanics*, 2007, Narosa Publishing House.
2. Alexander Verl, Alin Albu-Schaffer, Oliver Brock, Annika Raatz, *Soft Robotics Transferring Theory to Application*, Springer, 2015.
3. Jaeyoun (Jay) Kim , *Microscale Soft Robotics: Motivations, Progress, and Outlook*, Springer International Publishing, 2017.
4. Cecilia Laschi, Jonathan Rossiter, Fumiya Iida, Matteo Cianchetti, Laura Margheri, *Soft Robotics: Trends, Applications and Challenges*, Springer International Publishing, 2016.
5. Fahimi, Farbod. *Autonomous robots: modeling, path planning, and control*. Vol. 107. Springer Science & Business Media, 2008.

MTE 4082 SYSTEMS MODELING AND SIMULATION [3 0 0 3]

Introduction: **[06]**

Principles of Modeling & Simulation, Modeling & Simulation of mixed systems, Transfer function; Block Diagram; State Space Representation (MIMO).

Dynamic Systems: **[06]**

Electrical / Mechanical / Hydraulic / Acoustic Systems / Electromechanical / Thermal / Fluid / Mixed Systems/ Mechanical systems for Mechatronic Applications (Bond Graph Method)

Modeling 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 Behavior, 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.

MTE 4083 WIRELESS SENSOR NETWORKS [3 0 0 3]

Introduction: **[05]**
Challenges for wireless sensor networks, Comparison of sensor network with ad hoc network, 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, 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 (Querry 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, 2007.
2. Holger Karl and Andreas Willig, *Protocols and Architectures for Wireless Sensor Networks*, John Wiley & Sons, Ltd, 2005.
3. Ananthram Swami, Qing Zhao, Yao-Win Hong, Lang Tong Pub, *Wireless Sensor Networks Signal Processing and Communications*, John Wiley & Sons.
4. Murthy, *Ad Hoc Wireless Networks: Architectures and Protocols*, Pearson Education.
5. Sridhar S. Iyengar, NandanParameshwaran, Vir V. Phoha, N. Balakrishnan, Chuka D. Okoye, *Fundamentals of Sensor Network Programming: Applications and Technology*, John Wiley & Sons.

OPEN ELECTIVES

MTE 4301 AUTONOMOUS ROBOTS [2 1 0 3]

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 Manoeuvrability, Degree of mobility, Degree of steerability, Robot manoeuvrability, 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, To Localize or Not to Localize: 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.

References:

1. Roland Siegwart, Illah R. Nourbaksh , *Introduction to Autonomous Robots*, MIT Press, 2004.
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.

MTE 4302 ELECTRIC VEHICLE TECHNOLOGY [3 0 0 3]

Vehicle dynamics: **[10]**

Vehicle Resistance - Rolling Resistance, Aerodynamic Drag, Grading Resistance- Dynamic Equation, Tire–Ground Adhesion and Maximum Tractive Effort, Power Train Tractive Effort and Vehicle Speed, Vehicle Power Plant and Transmission Characteristics, Vehicle Performance- Maximum Speed of a Vehicle, Gradeability, Acceleration Performance. **Internal Combustion Engines:** Operating Principles -Operation Parameters- Rating Values of Engines, Pressure, Specific Fuel Consumption and Efficiency, Specific Emissions, Fuel/Air and Air/Fuel Ratio, Engine Performance Parameters

Hybrid and Electric Drive-trains: **[08]**

Configurations of Electric Vehicles, Performance of Electric Vehicles Traction Motor Characteristics, Tractive Effort and Transmission Requirement, Vehicle Performance, Basic concept of hybrid traction, hybrid drive-train architecture – series, parallel – torque and speed coupling, power flow control in hybrid drive-train topologies, fuel efficiency analysis.

Electric Propulsion unit: **[08]**

Introduction to electric components used in hybrid and electric vehicles, Different motors – DC motors, Induction motors, PMDC, Switched reluctance motors, Configuration and control of Motor drives, power modulators, Introduction to Energy Storage Requirements in Hybrid and Electric Vehicles, Control and Regenerative breaking: Different Electronic control Unit, Energy Management Strategies used in hybrid and electric vehicles, classification of different energy management strategies, comparison of different energy management strategies, implementation issues of energy management strategies, fundamentals of regenerative braking.

Sizing the drive system: **[06]**

Matching the electric machine and the internal combustion engine (ICE), Sizing the propulsion motor, sizing the power electronics, selecting the energy storage technology, Communications, supporting subsystems- Design of Series Hybrid Drive Train.

Fuel Cell Vehicles: **[04]**

Introduction to Fuel Cell Technology, Configuration, Control Strategy , Motor Power Design , Power Design of the Fuel Cell System, Design of the Power and Energy Capacity of the PPS, Design Examples.

References:

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

MTE 4303 HYDRAULICS AND PNEUMATICS SYSTEMS [2 1 0 3]

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: **[06]**

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: **[03]**

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: **[09]**

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.

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: **[09]**

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: **[02]**

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, 1999.
3. Scholz D., *Proportional Hydraulics*, Festo Didactic GMBH & Co, Germany, 2002.
4. Majumdar S.R., *Pneumatic Systems - Principles and Maintenance*, Tata McGraw Hill, 2000.
   Merkle D., Rupp K. and Scholz D., *Electrohydraulics Basic Level TP 601*, Festo Didactic GMBH & Co, Germany, 1994.

MTE 4304 INDUSTRIAL IoT [2 1 0 3]

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*, (1e), CRC Press, Boca Raton, London, 2002.
2. Silberschatz, Korth, Sudarshan, *Database System Concepts*, (6e), McGraw Hill, New York, 2011.
3. William Stallings, *Cryptography and Network Security: Principles and Practice*, (5e), Prentice Hall, 2010.

MTE 4305 INTRODUCTION TO ROBOTICS [2 1 0 3]

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.

Manipulator kinematics: **[05]**
Introduction to kinematics, link description, link-connection description, convention for affixing frames to links, manipulator kinematics, actuator space, joint space, and cartesian space, kinematics of two industrial robots, frames with standard names. Introduction to kinematics of parallel manipulators, Close loop constraints, four bar mechanism, Stewart platform

Inverse manipulator kinematics: **[05]**
Solvability, notion of manipulator subspace, algebraic solution by reduction to polynomial, pieper's solution when three axes intersect, examples of inverse manipulator kinematics, the standard frames, solving a manipulator, repeatability and accuracy.

Manipulator dynamics: **[05]**
Introduction, acceleration of a rigid body, mass distribution, Newton's equation, Euler's equation iterative Newton-Euler dynamic formulation, iterative vs. closed form, formulating manipulator dynamics in Cartesian space.

Trajectory generation: **[05]**

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

Linear control of manipulators: **[06]**

Introduction, feedback and closed-loop control, second-order linear systems, control of second-order systems, trajectory-following control, continuous vs. discrete time control, modeling and control of a single joint.

Lab Component-

Simulation of forward and inverse kinematics in computational software, Preliminary idea of master-slave control including hardware interfacing, Concept of Daisy Chain Network to control multiple actuators simultaneously.

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.

MTE 4306 MECHATRONICS SYSTEMS [2 1 0 3]

Mechatronic Engineering: **[05]**

Introduction, Mechatronic Systems, Modelling, and Design - Coupled Design, Mechatronic Design Quotient, Design Evolution, Evolution of Mechatronics, Application Areas.

Basic Elements and Components: **[05]**

Mechanical Elements: Mass, Spring, and Damper. Fluid Elements: Fluid Capacitor, resistor. Thermal Elements: Thermal capacitor, and resistor. Mechanical Components: transmission, lead screw and nut, and harmonic drives. Passive Electrical Elements and Materials, Active Electronic Components, Light Emitters and Displays and Light Sensors.

Modelling of Mechatronic Systems: **[05]**

Dynamic Systems and Models, Transfer Functions and Frequency-Domain Models, Equivalent Circuits and Linear Graph Reduction, Block Diagrams, Response Analysis, Computer Simulation.

Signal Conditioning: **[05]**

Impedance Characteristics, Amplifiers, filters, Modulators and Demodulators, Analog-to-Digital Conversion,

Sensors and Actuators: **[05]**

Potentiometer, Resolver, Encoders, Proximity Sensors, Tactile Sensors. Hydraulic, Pneumatic and Electrical Actuators.

Microcontrollers: **[05]**

Microcontroller Architecture, Input / Output Hardware, and Programming.

Case Studies in Mechatronics: **[06]**

Robotics Case Study, Hydraulics Based Case Study, Electrical Based Case Study, Pneumatics Based Case Study

References:

1. Clarence W. de Silva, *Mechatronics: A Foundation Course*, CRC Press, 2010.
2. Ganesh S. Hegde, *Mechatronics*, Laxmi Publications Pvt Ltd., 2011.