School of Automobile, Mechanical and Mechatronics

Department of Mechatronics

Master of Technology

(Industrial Automation and Robotics)

School of Automobile, Mechanical and Mechatronics Engineering Department of Mechatronics Engineering

M. Tech. in Industrial Automation and Robotics

Proposed Scheme for First Year (Total Credits 50/75)

Teaching Scheme			Contact Hours/Week				End-Term Exam Duration		Relative Weightage%				
Sem	**Code**	**Course Name**	**L**	**T**	**P**	**C**	**Th.**	**P.**	**CWS**	**PRS**	**MTE**	**ETE**	**PRE**
I Semester	MA 6101	Applied Numerical Analysis	3	0	0	3	3	-	20	-	40	40	-
	MC 6170	Research Methodology	3	0	0	3	3	-	20	-	40	40	-
	MC 6102	Robot Kinematics and Dynamics	3	1	0	4	3	-	20	-	40	40	-
	MC 6103	Advanced Control Theory	3	1	0	4	3	-	20	-	40	40	-
	MC 6104	Flexible Manufacturing Systems	3	0	0	3	3	-	20	-	40	40	-
	MC 6105	Advance Sensors, Drives and Actuators	3	0	0	3	3	-	20	-	40	40	-
	MC 61**	Program Elective - I	3	0	0	3	3	-	20	-	40	40	-
	MC 6130	PLC and Automation Lab	0	0	2	1	-	1	-	60	-	-	40
	MC 6131	Drives and Control lab	0	0	2	1	-	1	-	60	-	-	40
	MC 6132	CAD and Simulation Lab	0	0	2	1	-	1	-	60	-	-	40
		Total	**21**	**02**	**06**	**26**	**Total Contact Hours (L + T + P) = 29**						

Teaching Scheme			Contact Hours/Week				End-Term Exam Duration		Relative Weightage %				
Sem	**Code**	**Course Name**	**L**	**T**	**P**	**C**	**Th.**	**P.**	**CWS**	**PRS**	**MTE**	**ETE**	**PRE**
II Semester	MC 6201	Artificial Intelligence And Machine Learning	3	0	0	3	3	-	20	-	40	40	-
	MC 6202	Design of Locomotive Robots	3	1	0	4	3	-	20	-	40	40	-
	MC 6204	Design of Fluid Power Systems	3	0	0	3	3	-	20	-	40	40	-
	MC 6203	Image Processing and Machine Vision	3	0	0	3	3	-	20	-	40	40	-
	MC 62**	Program Elective - II	3	0	0	3	3	-	20	-	40	40	-
	MC 62**	Program Elective - III	3	0	0	3	3	-	20	-	40	40	-
	******	Open Elective	3	0	0	3	3	-	20	-	40	40	-
	MC 6230	Robotics Lab	0	0	2	1	-	2	-	60	-	-	40
	MC 6231	Seminar	0	0	2	1	-	1	100	-	-	-	-
		Total	**21**	**01**	**04**	**24**	**Total Contact Hours (L + T + P) + OE =26**						

School of Automobile, Mechanical and Mechatronics Engineering Department of Mechatronics Engineering

M. Tech. in Industrial Automation and Robotics

Proposed Scheme for Second Year (Total Credits 25/75)

Teaching Scheme			Contact Hours/Week				End-Term Exam Duration		Relative Weightage %				
Semeseter	**Code**	**Course Name**	**L**	**T**	**P**	**C**	**Th.**	**P.**	**CWS**	**PRS**	**MTE**	**ETE**	**PRE**
III and IV Semester	MC 7080	Dissertation	0	0	0	25	-	-	-	-	25	75	-
		Total				25							

List of Program Elective - I	
MC 6140	Linear Algebra for Modelling
MC 6141	Smart Material and Modelling
MC 6142	Application of Optimization Techniques
MC 6143	Industrial Project Management
List of Program Elective - II	
MC 6240	Intelligent Control System
MC 6241	Smart Manufacturing
MC 6242	Robot Path Planning and Motion Control
MC 6243	Advanced embedded systems and field programmable gate array
List of Program Elective - III	
MC 6251	Micro-electromechanical system
MC 6252	Advanced reliability engineering
MC 6253	Cyber physical system
MC 6254	Internet of Robotic Things

List of Open Elective	
MC 6270	Industrial automation
MC 6271	Introduction to robotic systems
MC 6272	Sensors application

ABBREVIATIONS	
L	Lecture
T	Tutorial
P	Practical
C	Number of Credits
Th.	Theory Course
P.	Practical (Laboratory) Course
CWS	Class Work Sessional
MTE	Mid-Term Exam
PRE	End Term Practical Exam
PRS	Practical Sessional
ETE	End Term Exam

MA 6101: APPLIED NUMERICAL ANALYSIS [3 0 0 3]

Mathematical modelling and engineering problem solving: simple mathematical model, conservation laws and engineering. Approximations and round of errors: Accuracy and precision, error definitions, round off errors, truncation errors and Taylor's series. Roots of equations: Bracketing methods, open methods, roots of polynomials applied to engineering problems. Linear algebraic equations: LU decomposition and matrix inversion, special matrices and Gauss Seidel applied to engineering problems. Numerical Differentiation and Integration: Newton Cotes Integration formulas, integration of equations, numerical differentiation applied to engineering problems. Ordinary Differential Equations: RK methods, Boundary value and Eigen value problems. Partial Differential Equations: Finite difference method for elliptic and parabolic equation applied to engineering problems.

References:

1. S.C. Chapra and R.P. Canale, *Numerical Methods for Engineers*, McGraw Hill Publication, 1998.
2. S.S. Sastry, *Numerical Analysis for Engineers*, McGraw Hill Publication, 2002
3. Cook, G., *Numerical Analysis, Modelling and Simulation*, Larsen and Keller Education, 2017
4. Jain, M.K., Iyengar, S.R.K, Jain, R.K, *Numerical Methods for Scientific and Engineering Computation*, NEW AGE; 6th edition, 2012

MC 6170: RESEARCH METHODOLOGY [3 0 0 3]

Mathematical tools for analysis, statistical analysis of data, regression analysis, correlation, concept of best fit and exact fit – Lagrange interpolation, Newton divided difference, least square regression. Design of experiment definition, objective, factorial design, designing engineering experiments, ANOVA, Fractional, Full and Orthogonal Experiments, Taguchi methods for robust design, response surface methodology. Engineering Optimization definition, basics of nonlinear optimization, formulation of optimization problems examples, Calculus techniques-Lagrange multiplier method – examples, nature inspired optimization techniques i.e. GA, PSO, SA etc., neural network based optimization, optimization using fuzzy systems. Sampling Techniques: basic terms, Importance of sampling in research, essentials of a good sample, sampling error, standard error of the mean (Standard Deviation), Estimation of parameters, accuracy & precision of estimation, sampling procedure, types/methods of sampling, Central limit theorem, sample size determination, confidence interval and Confidence level. Measurement & Scaling Techniques: - on different types of data, Types of Scales: Ratio, Interval, Ordinal Nominal. Mapping rules, characteristics of a good measurement, sources of error in measurement. Mathematical modelling of Engineering Systems Basic concepts of modelling of Engineering systems – Static and dynamic model – Model for prediction and its limitations, system simulation using tools like MATLAB, SPSS, Minitab, COMSOL, Ansys etc.- validation, use of optimization techniques – Genetic Algorithm, Simulated Annealing. Design of Experiments: Basic principles, Study of completely randomized and randomized block design.

References:

1. C R Kothari, *Research Methodology: methods and techniques*, New Age International Publication Ltd.
2. J W Creswell, *Research Design*, Sage South Asia Edition.
3. D G Montgomery, *Design and analysis of Experiments*, John Willy India Edition.

4. Stuart Melville and Wayne guddard, *Research Methodology an introduction for Science & Engineering Students*.
5. Ganesen MJP Publishers, *Research Methodology for Engineers,* Chennai, 201.

MC 6102: ROBOT KINEMATICS AND DYNAMICS [3 1 0 4]

Introduction: Position and orientation of objects, objects coordinate frame Rotation matrix, Euler angles Roll, pitch and yaw angles coordinate Transformations, Joint variables and position of end effector, Dot and cross products, coordinate frames, Rotations, Homogeneous coordinates. Direct Kinematics: Link coordinates D-H Representation, The arm equation. Direct kinematic analysis for Four axis, SCARA Robot and three, five and six axis Articulated Robots. Inverse Kinematics: The inverse kinematics problem, General properties of solutions. Tool configuration, Inverse kinematics of four axis SCARA robot and three and five axis, articulated robot.Differential Kinematics: Differential Relationships, Jacobian, Differential Motions of a Robot and its Hand Frame, Calculation of the Jacobian, Inverse Jacobian. Manipulator Dynamics: kinetic and potential energy equations, Gravity, Generalized forces, Lagrange-Euler Dynamic model, Dynamic model of a Two-axis planar robot, Newton Euler formulation, Lagrange - Euler formulation, problems.Trajectory Planning: The Trajectory Planning Problem, Trajectories for Point to Point Motion, Cubic Polynomial Trajectories, Multiple Cubic, Quintic Polynomial Trajectories, Linear Segments with Parabolic Blends (LSPB), Minimum Time Trajectories Applications of motion control of manipulators.

References:

6. Spong, Mark W., and MathukumalliVidyasagar. Robot dynamics and control. John Wiley & Sons, 2008.
7. Craig. J. J. “Introduction to Robotics Mechanics and Control”, Addison- Wesley, 1999
8. Richard D. Klafter, Thomas .A, ChriElewski, Michael Negin, “Robotics Engineering an Integrated Approach”, Phi Learning., 2009.
9. Francis N. Nagy, AndrasSiegler, “Engineering Foundation of Robotics”, Prentice Hall Inc., 1987.
10. Fu. K. S., Gonzalez. R. C. & Lee C.S.G., “Robotics Control, Sensing, Vision and Intelligence”, McGraw Hill Book co, 1987.

MC 6103: ADVANCED CONTROL THEORY [3 1 0 4]

Non Linear System- Phase Plane Analysis, Linearization, Describing Function method, Limit Cycle, Controllability and Observability of Non Linear System, Lyapunov Stability, Kalman Filter, Sliding Mode Control, System Identification, Control Algorithms for MIMO System-Robust, Optimal and Adaptive Control, Robotic Applications-State observation and feedback control in robotic system.

References:

1. Burns, Roland. Advanced Control Engineering. United Kingdom: Elsevier Science, 2001.

2. M. Athans and P. L. Falb, “Optimal Control: An Introduction to the Theory and Its Applications”, Dover Books on Engineering, 2006.
3. Mackenroth, Uwe. Robust Control Systems: Theory and Case Studies. Germany: Springer Berlin Heidelberg, 2013.
4. Tarn, T. J Control in Robotics and Automation: Sensor-based Integration. United Kingdom: Academic Press. (1999).
5. Control Systems Design of Bio-Robotics and Bio-Mechatronics with Advanced Applications. (2019). Netherlands: Elsevier Science

MC 6104: FLEXIBLE MANUFACTURING SYSTEMS [3 0 0 3]

Introduction to Robotics and FMS: Robot anatomy; Overview of PLC, Sensors and Pneumatics; Introduction to FMS and its components; FMS in robotics; Flexible Assembly Systems; Forward and inverse kinematics; System Support Equipment: Industrial parts feeding and assembly- parts-feeders and jigs; flexible fixturing; assembly planning; automated assembly systems; Vibratory bowl feeders, non-vibratory feeders; Automated Guided Vehicle (AGV), Automated Storage Retrieval System (ASRS) FMS Planning Problems: Pallets & Fixtures; Material Handling System; Queuing; Petri Nets; Strategic Planning; Review of FMS Planning Models; IE methods/algorithms to plan robotic cells, lines, teams, swarms, MRPII and JIT manufacturing systems, Classification of FMS layouts Robots and autonomous systems: Scheduling of Parts, Machines, Robots, Tools, etc.; Process Monitoring and Control Procedures; Robot simulators and emulators; Robot cognition, interaction, intelligence, and social behaviour; Robots & sustainability-Eco-robots, renewable energy-powered robots.

References:

1. W.W. Luggen: Flexible Manufacturing Cells and Systems, Prentice-Hall International, Inc., 1991.
2. Siciliano, Bruno, and Oussama Khatib, eds. Springer handbook of robotics. Springer Science & Business Media, 2008.
3. Shimon Y. Nof. Handbook of Industrial Robotics, Vol. 1. John Wiley & Sons, 1999.
4. S.B. Joshi, and J.S. Smith (ed.): Computer Control of Flexible Manufacturing Systems, Research and Development, Chapman & Hall, 1994.
   P.J. O'Grady: Controlling Automated Manufacturing Systems, Kogan Page, 1986

MC 6105: ADVANCE SENSORS, DRIVES AND ACTUATORS [3 0 0 3]

Sensor performance criteria and selection, thermal sensors, gyroscope and accelerometers, bio-sensors, gas sensors, vision sensors, tactile sensor, LiDAR sensor, magnetic sensors, piezoelectric sensors, proximity sensors, ultrasonic sensors, optical sensors, classification of low power and high power drives; introduction of low power drives, speed control of DC motors, speed control of induction Motors, speed and direction control of stepper motors, speed and position control of servo motors, speed control of BLDC motor, piezoelectric actuators, shape memory alloy actuators.

References:

1. C. deSilva, *Control Sensors and Actuators*, Prentice Hall, 1989
2. R. Krishnan,*Electric Motor Drives: Modeling, Analysis, and Control*, Prentice Hall, 2001
3. T. Kenjo,*Electric Motors and Their Controls*, Oxford, 1991
4. G. K. Dubey, *Fundamentals of Electric Drives*, Narosa publications, 2nd edition, 2001.
5. Jacob Fraden, *Handbook of modern Sensors,* AIP Press, Woodbury, 1997.

MC 6140: LINEAR ALGEBRA FOR MODELLING [3 0 0 3]

The geometry of linear equations, Column space and null-space, Elimination with matrices, Factorization, Orthogonal vectors and subspaces, Projection matrices and least squares, Cramer's rule, inverse matrix, and volume, Diagonalization and powers of A, Differential equations and exp(At), Linear transformations and their matrices, Change of basis: image compression, Four Ways to Solve Least Squares Problems, Singular value decomposition for data compression, gradient descent, finding cluster in graphs. Modelling applications.

References:

1. Strang, G., *Linear algebra and learning from data*, Wellesley-Cambridge Press, 2019.
2. Strang, G., *Linear Algebra and Its Applications*, Cengage Learning (RS); 4th edition, 1982.
3. Boyd, S., and Vandenberghe, L., *Introduction to applied linear algebra: vectors, matrices, and least squares*, Cambridge university press, 2018
4. Singh, K., *Linear Algebra: Step by Step*, OUP Oxford, 1st Edition, 2014

MC 6141: SMART MATERIAL AND MODELLING [3 0 0 3]

Composites, Smart materials and their properties, Piezoelectric, magneto structure, Shape memory materials, Optical fibers, actuation, sensing and control augmentation, distributed/discrete sensing and actuation, methods of analyses, finite elements, and applications. Semiconductor materials, Wafer Technology, Basic patterning and surface preparation to exposure, photomasking, photoresist and their performance factors, Etching, dry and wet etching, resistor stripping, chemical vapor deposition (CVD), Plasma Enhanced CVD, Vapor phase epitaxy, molecular beam epitaxy, MOCVD, deposited films, Photolithography process, Antireflective coatings. Significance, properties and applications nanomaterials, carbon nano structures, quantum confinement, effect of size reduction on optical, electrical, electronic, mechanical, magnetic and thermal properties of materials, nano electronics, NEMS, photonic crystals, biomimetic nano structures.

References:

1. Gandhi M V and Thompson B S, *Smart Materials and Structures*, Chapman & Hall, Madras, 1992.
2. Meirovitch L., *Dynamics and Control of Structures*, John Wiley, 1992.
3. Sulabha K. Kulkarni, *Nanotechnology Principles and Practices*, Capital Publishing Company, 2007.
4. Surender Kumar*, Principles of Metal Working,* Oxford & IBH Publishing Company, New Delhi 2001.
5. H. Hosono, Y. Mishima, H. Takezoe and K.J.D Mackenzie, *Nanomaterials from Research to Applications*, Elsevier Ltd., Noida, 2008.

MC 6142: APPLICATION OF OPTIMIZATION TECHNIQUES [3 0 0 3]

Single Variable Non-Linear Unconstrained Optimization: One dimensional Optimization methods: -Uni-modal function, elimination methods, Fibonacci method, golden section method, interpolation methods – quadratic & cubic interpolation methods.Multi variable non-linear unconstrained optimization, Non-traditional optimization Techniques, Optimised vehicle Dynamics using Metaheuristic optimization, Interactive optimization of path planning of a Robot, Box type Boom Design using Surrogate Modelling-Industrial Optimisation benchmark

References:

1. Rhinehart, R. Russell*. Engineering Optimization: Applications, Methods and Analysis*. United Kingdom: Wiley, 2018..
2. Heinz D. Unbehauen. *Control Systems, Robotics and Automation – Volume XVI: Fault Analysis and Control.* N.p.: EOLSS Publications, 2009.
3. Yang, Xin-She. *Optimization Techniques and Applications with Examples*. United States: Wiley, 2018.
4. Babu, B. V.., Onwubolu, Godfrey C.. *New Optimization Techniques in Engineering*. Germany: Springer Berlin Heidelberg, 2013.

MC 6143: INDUSTRIAL PROJECT MANAGEMENT [3 0 0 3]

Project management: functions, attributes and processes what is a project features of a project project life cycle a project management sample. Introduction phases of project management & network diagrams guidelines CPM, Gantt chart time chart PERT crashing of project appraisal methods in project market appraisal technical appraisal environmental appraisal environment & pollution S C B A Unido approaches, lm approaches, CSR in project management financial appraisal, time value of money, cost of capital, fundamentals of capital budgeting, risk analysis models, project risk management, simple probability analysis, sensitivity analysis, scenario analysis break-even analysis risk adjusted discount rate method decision tree analysis financial forecasting financial forecasting percentage of sales method financing strategy cost of project means of finance capital structure infrastructure financing project stakeholders project contracts project planning the process of planning components of a good plan planning inputs required for project planning why does a project fail reason behind time over-run & cost over-run project execution project organization project staffing project budgeting project scheduling project control & audit project monitoring & control termination of a project project audit e-project what is e-project planning of e-project resource analysis of e-project cost of e-project valuation of e-project financing of e-project future of e-project. Case studies of different project scenarios and project report.

References:

1. Prasanna Chandra, '*Projects Planning, analysis, Financing , Implementation and Review Management'*, V Edition Tata McGraw Hill, 2004.
2. Choudhury, S.,*'Project management*', Tata McGraw Hill, 27th reprint 2007.
3. Shitangshu Khatua *Project management and Appraisal* Oxford University Press 2011
4. Clifford F Gray, *Project Management: The Managerial Process,* Mc Graw Hill 2017

MC 6130: PLC AND AUTOMATION LAB [0 0 2 1]

Basics of ladder logic programming, stepper motor: direction and speed control, traffic light system: open loop and closed loop control, lift control system, controlling of bottle filling system, PLC controlled electro-hydraulic system, PLC controlled electro-pneumatic system, induction motor control: speed and direction, conveyor belt control.

References:

1. F. D. Petruzella, *Programmable Logic Controllers*, 4th edition, McGraw- Hills Publications, 2010.
2. *Siemens PLC Handbook*, Siemens Inc.
3. John W. Webb and Ronald A. Reiss, *Programmable logic controllers-Principle and applications*, 5th edition, PHI, 2003.
4. Khaled Kamel, Eman Kamel, *Programmable Logic Controllers: Industrial Control*, McGraw-Hill Education, 2013

MC 6131: DRIVES AND CONTROL LAB [0 0 2 1]

Position control for Stepper motors, servo motors, linear motors etc. Configuring masters and slaves, synchronizing master & slave, making drives PLC enabled, restructuring encoders, running motors in translation and rotation mode, position & velocity control, PLC programming – pick and place operation, tracing drive parameters. Speed and direction control for Stepper motors, servo motors, linear motors etc Implementation and tuning of various configuration of PID controllers.

References:

1. *Drives and Control training system practice module*, BOSCH REXROTH manual Germany 2011
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.
4. Hackworth and Hackworth F.D, Programmable logic controllers- Programming Method and applications, Pearson, 2004

MC 6132: CAD AND SIMULATION LAB [0 0 2 1]

Simulation of robot models using Robot Operating System and Gazebo; Introduction to Finite Element Analysis, Ansys workbench, Meshing, Static structural, Thermal analysis, Ansys with MEMS; Matlab and Ansys integration; Forward and inverse kinematics of robot coordinate systems.

References:

1. Amos Gilat, *MATLAB: An Introduction with Applications*, (5e), Wiley Publication, 2014.
2. Stormy Attaway, *MATLAB: A Practical Introduction to Programming and Problem Solving*, (4e), Butterworth-Heinemann Publication, 2016.
3. Anand Jayakumar Arumugham, *Ansys and Matlab: Laboratory Manual,* Notion Press, 2020.

4. Morgan Quigley, *Programming Robots with Ros: A Practical Introduction To The Robot*, O'Reilly Media, 2015

MC 6201: ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING [3 0 0 3]

Introduction to artificial intelligence, uninformed search, heuristic search, stochastic search, adversarial search, constraint satisfaction problem, markov decision processes, propositional logic and first order logic, bayesian networks, machine learning: introduction, decision tree, ensemble, bayesian rule, k-nearest-neighbour, support vector machines, clustering and unsupervised learning, case studies: robotics application, intelligent control.

References:

1. Stuart Russell and Peter Norvig, *Artificial Intelligence, A Modern Approach*, 3rd Edition, Pearson Education, 2015.
2. EthemAlpaydin, *Introduction to Machine Learning*, (3e), MIT Press, 2014
3. Francis X. Govers, *Artificial Intelligence for Robotics: Build intelligent robots that perform human tasks using AI techniques*. Packt Publishing, 2018.
4. Andreas C. Muller & Sarah Guido, *Introduction to Machine Learning with python: A guide for Data Scientists*, O'Reilly (3e), 2017.

MC 6202: DESIGN OF LOCOMOTIVE ROBOTS [3 1 0 4]

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, Kinematic Models and Constraints, Perception, Sensors for Mobile Robots, Sensor classification, Characterizing sensor performance Mobile Robot Localization, The Challenge of Localization: Noise and Aliasing, Planning and Navigation, Competences for Navigation: Planning and Reacting

References:

1. Roland Seigwart and Illah R. Nourbakhsh, *Introduction to Autonomous Mobile Robots*, The MIT Press Cambridge, Massachusetts London, England, 2nd Edition, 2011.
2. Nehmzow, Ulrich, *Mobile Robotics: A Practical Introduction*, Springer-Verlag London, 2nd Edition, 2003.
3. Gregor Klancar, Andrej Zdesar, Saso Blazic and Igor Skrjanc, *Wheeled Mobile Robotics: From Fundamentals Towards Autonomous Systems*, Elsevier, 1st Edition, 2017.
4. Eugene Kagan, Nir Shvalb and Irad Ben-Gal, *Autonomous Mobile Robots and Multi-Robot Systems: Motion-Planning, Communication, and Swarming*, Wiley Publisher, 2019.

MC 6203: IMAGE PROCESSING AND MACHINE VISION [3 0 0 3]

Fundamentals of Image processing, Image compression and enhancement techniques, Active vision and Machine vision components - hardware and algorithms, image properties and function, algorithms for data reduction, segmentation, feature extraction and edge detection, Image classification and decisions, machine-learning algorithms in image processing. Machine Vision Overview, application of machine vision in robotics and Industrial automation.

References:

1. Gonzalez, R. and Woods,R., *Digital Image Processing*, Pearson, 4th Edition, 2018.
2. A. K. Jain, *Fundamentals of Digital Image Processing*, Pearson Education, Reprint 2015
3. Gonzalez, R., Woods,R., Eddins, S., *Digital Image Processing Using MATLAB*, McGraw Hill Education, 2nd Edition, 2017.
4. Jain, R., *Machine Vision,* Indo American Books, 1st Edition, 2017
5. Solem, Eric, J., *Programming Computer Vision with Python*, O'Reilly, 1st Edition, 2012

MC 6204: DESIGN OF FLUID POWER SYSTEMS [3 0 0 3]

Introduction to Fluid Power Automation, Types of automation; Benefits and Impact of Automation on Manufacturing and Process Industries. Hydraulic & Pneumatic Comparison – ISO symbols for fluid power elements, Hydraulic, pneumatics – Selection criteria. Reservoir capacity, heat dissipation, accumulators and their types. Applications of Accumulator circuits. Standard circuit symbols, circuit (flow) analysis. Different types of compressors and Actuators in Pneumatics, their applications and use of their ISO symbols. Circuit Design Basic Hydraulic Circuits: Pneumatic Circuit Designing: Design of Pneumatic sequencing circuits using Cascade method and Shift register method. Electro Pneumatics & Electronic Control Of Hydraulic and Pneumatic Circuits: Design of Electro-Pneumatic Circuits; Digital Hydraulics: Definition & Introduction, Digital vs. analog hydraulic control; Application case studies.

References:

1. Mikell P. Groover, Automation, *Production Systems, and Computer-integrated Manufacturing,* (3rdEdition), PHI Learning Private Limited, New Delhi, 2008.
2. Joji P., *Pneumatic Controls*, Wiley India Pvt. Ltd., 2008.
3. Peter Croser, Frank Ebel, *Pneumatics Basic Level*, Festo Didactic GmbH & Co. Germany.
4. Prede G., Scholz D., *Electropneumatics Basic Level,* Festo Didactic GmbH & Co. Germany.
5. Bliesener R., Ebel F., Loffler C., Plagemann B., Regber H., Terzi E. V., Winter A., *Programmable logic controllers Basic Level,* Festo Didactic GmbH & Co. Germany

MC 6240: INTELLIGENT CONTROL SYSTEM [3 0 0 3]

Intelligent Systems, Control and Intelligent Systems, Dimensions of Intelligent Systems; Techniques in Intelligent Control; Control System Architectures; Need for Learning, Learning and Adaptation, Learning Algorithms, Decision-Making Techniques-Expert Systems - Components of an Expert System, Different Development Levels in Expert Systems, Neural Network Architectures for Modeling and Control in Representation of Plants; Modeling Architecture; Supervised Control Architectures, Neuro-Fuzzy Identifiers, Self-Organizing Fuzzy Logic Control, Intelligent control in Contemporary Robotics.

References:

1. Lakner, R.., Gerzson, M.., Szederkényi, Gábor., Hangos, Katalin M.. *Intelligent Control Systems: An Introduction with Examples*. Netherlands: Springer US, 2006.

2. Sahin, Ferat., Nanayakkara, Thrishantha., Jamshidi, Mo*. Intelligent Control Systems with an Introduction to System of Systems Engineering*. United States: CRC Press, 2018.
3. Nair, Ranjith,Ravindranathan., Dutta, Samrat., Behera, Laxmidhar., Kumar, Swagat., Patchaikani, Prem Kumar. *Intelligent Control of Robotic Systems*. United States: CRC Press, 2020.
4. 4. Katic, D., Vukobratovic, M*. Intelligent Control of Robotic Systems*. Germany: Springer Netherlands. 2013

MC 6241: SMART MANUFACTURING [3 0 0 3]

Introduction to smart manufacturing: -Smart Manufacturing Processes- Three Dimensions: Demand Driven and Integrated Supply Chains; Dynamically Optimized Manufacturing Enterprises (plant + enterprise operations) ; Real Time, Sustainable Resource Management (intelligent energy demand management, production energy optimization and reduction of GHG). Smart design/fabrication - Digital Tools, Product Representation and Exchange Technologies and Standards, Agile (Additive) Manufacturing Systems and Standards. Mass Customization, Smart Machine Tools, Robotics and Automation (perception, manipulation, mobility, autonomy), Smart Perception – Sensor networks and Devices. Introduction to Smart Communication systems Information, Mobility, Communication Technologies, Protocols, Cyber Physical Systems – the next generation of Embedded Systems and Networks, Smart Cloud- Hyper scale Computing; Application Delivery Platforms and Platform as a Service; Intelligent Analytics Services. Smart Applications: Online Predictive Modeling, Monitoring and Intelligent Control of Machining/Manufacturing and Logistics/Supply Chain Processes; Smart Energy Management of manufacturing processes.

References:

1. McEwen and H. Cassimally, *Designing the Internet of Things*, 1st edition, Wiley, 2013.
2. N. Vengurlekar and P. Bagal, *Database Cloud Storage: The Essential Guide to Oracle Automatic Storage Management*, 1st edition, McGraw-Hill Education, 2013.
3. M. Kuniavsky, *Smart Things: Ubiquitous Computing User Experience Design*, 1st edition, Morgan Kaufmann, 2010.
4. V.K.Jain, *Advanced Machining Processes*, Allied Publications, 1st edition, 2007.
5. John A Schey, *Introduction to Manufacturing Processes*, Mc Graw Hill, 3rd edition, 2012.

MC 6242: ROBOT PATH PLANNING AND MOTION CONTROL [3 0 0 3]

Introduction to navigation and motion planning, workspace vs. configuration space,geometric motion planning problem, motion planning as an optimal control problem,formulation of motion planning in a discrete domain, navigation potential functions, Roadmaps: visibility graph, generalised Voronoi diagram, silhouette; cell decompositions: trapezoidal, Morse cell decomposition, sampling-based planning methods (probabilistic roadmap, Rapidly-Exploring Random Trees),Bayesian methods, Kalman filtering, graph search algorithms, A* search algorithm and examples.motion planning, and control-based planning, manipulation planning, optimal planning, feedback planning

References:

1. FarbodFahimi, "*Autonomous Robots- Modeling, Path Planning, and Control"* (1e) Springer, 2009.
2. H. Asada and J. J. Slotine, "*Robot Analysis and Control*" Springer Verlag, 1998.
3. YasminaBestaouiSebbane, "*Planning and Decision Making for Aerial Robots*", (1e), Springer, 2014.
4. Choset H., Lynch K. M., "*Principles of Robot Motion: Theory "Algorithms, and Implementations*" (1e), MIT Press, Boston, 2005

MC 6243: ADVANCED EMBEDDED SYSTEMS AND FIELD PROGRAMMABLE GATE ARRAY [3 0 0 3]

Introduction to reconfigurable and FPGA based system Design; Basic and Advanced FPGA Fabrics; Combinational and Sequential logic realization on FPGA; Issues on FPGA based system Design: Area, Timing and Power; Design; Behavioral /high level Design and implementation methodologies: HDL, IP Core, System Generator; Processor and memory cores; Timing analysis; Clock distribution and management systems; Large scale System Design: Platform FPGA, Multi-FPGA System; Busses and I/O communication system; DSP system Design and Implementation using FPGA; Introduction to FPGA based Embedded system platform.

References:

1. Wayne Wolf, *FPGA-Based System Design*, Prentice Hall Modern Semiconductor Design Series, 2004.
2. Ron Sass and Andrew G. Schmidt, Morgan Kaufmann*, Embedded System design with Platform FPGAs*, Elsevier,2010.
3. Steve Kilts, Advanced FPGA design – Architecture, *Implementation and Optimization*, Wiley publications,2007.
4. K. V. Shiva, *Introduction to Embedded Systems*, Tata McGraw Hill, 2009

MC 6251: MICRO-ELECTROMECHANICAL SYSTEM [3 0 0 3]

Overview of Mems and Microsystems: MEMS & Microsystems and its evolution, Microsystems & Miniaturization, Micro sensors and actuators, Micro accelerometers, Introduction to NEMS; Engineering Science for Microsystems Design and Fabrication: Ions and Ionization, Molecular Theory and atomic structure of Matter, Doping of Semiconductors, Diffusion Process, Plasma Physics, Quantum Physics; Engineering Mechanics and Thermo Fluid Engineering for Microsystems Design: Static Bending of Thin Plates, Thermo mechanics, Fluid Mechanics in Macro and Mesoscales, Laminar Fluid Flow in Circular Conduits, Incompressible Fluid Flow in Micro conduits; MEMS Sensors and Actuators: Capacitive and Piezo Resistive Pressure sensors, Actuation using piezoelectric crystals, thermal forces, etc, Actuation using Electrostatic forces (Parallel plate, Torsion bar, Comb drive actuators); MEMS Technology: RF MEMS, MEMS simulators, MEMS Packaging, MEMS Transducers, Optical MEMS, Bio MEMS, Plastic MEMS; Modelling Resonators; MEMS in IoT; Micro-robots; Materials for MEMS: Substrates and Wafers, Photolithography, Ion implantation, Diffusion and oxidation, Etching, Bulk micro manufacturing, Surface Micromachining, LIGA Process.

References:

1. Marc Madou, "*Fundamentals of Micro fabrication*", CRC press 1997.
2. Stephen D. Senturia," *Micro system Design*", Kluwer Academic Publishers,2001
3. Maluf, M., "*An Introduction to Microelectromechanical Systems Engineering*", Artech House, Boston, 2000
4. Trimmer, W.S.N., "*Micro robots and Micromechanical Systems*", Sensors & Actuators, vol. 19, no.1989

MC 6252: ADVANCED RELIABILITY ENGINEERING [3 0 0 3]

Introduction and Overview, Constant failure rate model, Time-dependent failure model, Reliability of system, State dependent system, Modelling and Evaluation Techniques-II, Standby/Partial Standby model, Load Sharing Model, Tri-State Model. Interference Theory and Stress-Stress Models Interference Theory and Reliability Computation: General expressions, Reliability Computation for different types of similar/dissimilar stress-strength distributions, Graphical Approach. Time Dependent Stress Strength Model, SS Classification, reliability computation for Deterministic/Random Cycle times, Reliability in case of aging, cyclic damage, and cumulative damage. Maintainability and Availability, Markov State Model for non-maintained/maintained Systems: Reliability/Availability Modelling for single unit, standby, two units with/without joint servicing. Fault Tree Analysis, Definitions and Symbols, Construction, Simplification, Fault tree evaluation: Qualitative and Quantitative, Special Systems Models and Reliability Evaluation, Phased-mission Systems, Common-cause Failure Modelling, Introduction to Multistate Systems. Reliability Testing, Types of Reliability Testing, ALT and ALT models (Statistics, Physics-Statistics, Physics Experimental based models), Degradation Models, Basic ALT plans. Sample Case Studies

References:

1. K. B. Misra, *Reliability Analysis and Prediction: A Methodology Oriented Treatment*, Elsevier Science, 1992
2. Patrick D. T. O'Connor and Andre Kleyner*, Practical Reliability Engineering*, Wiley, 2012.
3. Elsayed A. Elsayed*, Reliability Engineering*, John Wiley, 2nd Ed, 2012
4. Charles E. Ebling, *Reliability and Maintainability Engineering*, TMH, 9th Reprint, 2008.
5. K. C. Kapur and L. R. Lamberson, *Reliability in Engineering,* Design, Wiley India, 2009.

MC 6253: CYBER PHYSICAL SYSTEMS [3 0 0 3]

Cyber-Physical Systems (CPS) in the real world, basics of cyber physical system, components of cyber physical system, wireless sensor network, control of CPS: event triggered control, distributed control, control challenges; Lyapunov stability theory, networked control system (NCS), security of cyber physical systems, case studies.

References:

1. Edward Ashford Lee, Sanjit Arun kumar Seshia, *Introduction to embedded systems: A cyberphysical systems approach*, United Kingdom: Lulu.com, 2011.
2. Rajeev Alur, *Principles of Cyber-Physical Systems,* MIT Press, 2015.
3. Marilyn Wolf, *High-Performance Embedded Computing: Applications in Cyber-Physical Systems and Mobile Computing*, Elsevier Science, 2014.
4. Danda B. Rawat, Sabina Jeschke, Christian Brecher, *Cyber-Physical Systems Foundations, Principles and Applications*, Elsevier Science, 2016.

MC 6254: INTERNET OF ROBOTIC THINGS [3 0 0 3]

Introduction to Internet of Robotic Things (IoRT) - Definition, Taxanomy Industrial IoRT- Layers: IoRT Sensing, Platform Architecture, Processing Communication, Networking, Challenges, Emerging IoRT technologies IoRT impact on intelligence, Big Data Analytics and Software Defined Networks: IoRT Analytics, Application Domains, Collaborative robots, Industry 4.0 and IoRT.

References:

1. Giacomo Veneri, Antonio Capasso, *Hands-On Industrial Internet of Things: Create a Powerful Industrial IoT Infrastructure Using Industry 4.0,* United Kingdom: Packt Publishing, 2018.
2. Rusu, Cristian., Culic, Ioana., Radovici, Alexandru. *Commercial and Industrial Internet of Things Applications with the Raspberry Pi: Prototyping IoT Solutions*. Germany: Apress, 2020.
3. Gilchrist, Alasdair. *Industry 4.0: The Industrial Internet of Things,* United States: Apress, 2016.
4. Bhattacharjee, Sravani. *Practical Industrial Internet of Things Security: A Practitioner's Guide to Securing Connected Industries,* United Kingdom: Packt Publishing, 2018.
5. Malik, P. K., Gehlot, A., Jain, V. (2019*). Handbook of Research on the Internet of Things Applications in Robotics and Automation,* United States: IGI Global.

MC 6270: INDUSTRIAL AUTOMATION [3 0 0 3]

Introduction: Definition, principles and strategies, advanced functionalities, Information processing in manufacturing industry, Production concepts and automation strategies; Fixed Automation: Automated Flow lines, Methods of Work part Transport, Transfer Mechanism; Indexing mechanism, Buffer Storage, Automation for Machining Operations. Analysis of Automated Flow Lines; Assembly Systems and Line Balancing; Methods of Line Balancing, Flexible Manual Assembly Lines. Automated Assembly Systems: Design for Automated Assembly and Types of Automated Assembly Systems; Analysis of Multi-station Assembly Machines, Analysis of a Single Station Assembly Machine Automated Materials Handling: The material handling function, Types of Material Handling Equipment, Analysis for Material Handling Systems, Design of the System, Conveyor Systems, Automated Guided Vehicle Systems. Automated Storage

Systems: Storage System Performance, Automated Storage/Retrieval Systems, Carousel Storage Systems, Work-in-process Storage, Interfacing Handling and Storage with Manufacturing. Automated Inspection and Testing: Inspection and testing, Statistical Quality Control, Automated Inspection Principles and Methods, Sensor Technologies for Automated Inspection, Coordinate Measuring Machines, Other Contact Inspection Methods.

References:

1. M.P.Grover, *Automation, Production Systems and Computer Integrated Manufacturing*- Pearson Education.
2. Amber G.H & P.S. Amber *Anatomy of Automation*, PrenticeHall.
3. N. Viswanandham, Y. Narahari *Performance Modeling of Automated Manufacturing Systems*, 1st Edition, 2009.
4. C.Ray Asfahl, *Robots and manufacturing Automation*, John Wiley and Sons New York, 1992.

MC 6271: INTRODUCTION TO ROBOTIC SYSTEMS [3 0 0 3]

Introduction: Robot anatomy, Robot classifications-Architecture of robotic systems, Terminology of Robotics Accuracy and repeatability of Robotics, Simple problems, Specifications of Robot, Robot joints and links, -Robot Drive systems-Hydraulic, Pneumatic and Electric system. End effectors and robot controls: Mechanical grippers, Gripper force analysis, Gripper design, Simple problems-Robot controls-Point to point control, Continuous path control. Robot transformations: Robot kinematics-Types- 2D, 3D Transformation-Scaling, Rotation, Translation Homogeneous coordinates, Simple problems. Sensors in robot: Touch sensors-Tactile sensor, Proximity and range sensors, Robotic vision sensor-Force sensor-Light sensors, Pressure sensors. Robot applications: Robot work cell design and control-Sequence control, Operator interface, Safety monitoring devices in Robot-Mobile robot working principle, -Robot applications- Material handling, Machine loading and unloading, assembly, Inspection, Welding, Spray painting and undersea robot. Micro/nano robotics: Micro/Nanorobotics system overview-Actuators of Micro/Nano robotics system-Nanorobot communication techniques-Fabrication of micro/nano grippers-Biomimetic robot-Swarm robot-Nanorobot in targeted drug delivery system.

References:

1. Spong, Mark W., and Mathukumalli Vidyasagar. *Robot dynamics and control,* John Wiley & Sons, 2008.
2. Craig. J. J. *Introduction to Robotics Mechanics and Control*, Addison- Wesley, 1999
3. Bharat Bhushan., "*Springer Handbook of Nanotechnology*", Springer, 2004.
4. Julian W. Gardner., "*Micro sensor MEMS and Smart Devices*", John Wiley & Sons, 2001

MC 6272: SENSORS APPLICATION [3 0 0 3]

Sensor performance criteria and selection, Sensor characteristics, Calibration, Typical faults, Trouble shooting, Techinques of performance enhancements, Types of basic sensors, Analytical sensors: Chemical

Sensors, Polarization, Polarizable, Non polarizable electrodes and body surface recording electrodes, Bio-sensors: ECG, EEG, electrodes ECG signals, waveforms. Data acquisition and processing techniques for sensors.

References:

1. Patranabis D., *Sensors and Transducers*, Prentice Hall India Learning Private Limited; 2nd edition (1 January 2003)
2. *Control Sensors and Actuators*, C. deSilva, Prentice Hall, 1989
3. Alegret S., *Electrochemical Sensor Analysis (Volume 49)*, Elsevier Science, 2007
4. Alice J. Cunningham, *Introduction to Bioanalytical Sensors,* Wiley-Interscience; 1st edition (20 May 1998)

MC 6230: ROBOTICS LAB [0 0 2 1]

Kinematics of robot manipulator, Dynamics of robot manipulator, Control of robot manipulator (open loop and closed loop, point to point and continuous motion control), Robot differential kinematics, Mobile robot kinematics, Mobile robot Dynamics, Control of Mobile robot (open loop and closed loop), Robot path planning, Simulation of robot kinematics and dynamics using Software, Application of robots for writing, pick and place, Programming of robot using Matlab or ROS.

References:

1. Spong, Mark W., and Mathukumalli Vidyasagar. "*Robot dynamics and control*". John Wiley & Sons, 2008.
2. Craig. J. J. "*Introduction to Robotics Mechanics and Control*", Addison- Wesley, 1999
3. Klancar, Gregor, Andrej Zdesar, Saso Blazic, and Igor Skrjanc. "*Wheeled mobile robotics: from fundamentals towards autonomous systems*". Butterworth-Heinemann, 2017.
4. Martinez, Aaron, and Enrique Fernández. "*Learning ROS for robotics programming*". Packt Publishing Ltd, 2013.
5. Corke, Peter. "*Robotics, vision and control: fundamental algorithms in MATLAB®*", second, completely revised. Vol. 118. Springer, 2017.

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