Course No.	Course Name	L-T-P	Credits	Year of Introduction
08GN6001	Research Methodology	0-2-0	2	2019

Course Objectives

The main objective of the course is to provide a familiarization with research methodology and to induct the student into the overall research process and methodologies.

This course addresses:

- The scientific research process and the various steps involved formulation of research problem and research design, design of experiments, thesis preparation and presentation, research proposals, publications and ethics;
- Important research methods in engineering

As a tutorial type course, this course is expected to be more learner centric and active involvement from the learners are expected which encourages self-study and group discussions. The faculty mainly performs a facilitator's role.

Syllabus

Overview of research methodology- research process- scientific methods- research problem and design- research design process- formulation of research task, literature review and web as a source- problem solving approaches- experimental research- ex post facto research. Thesis writing- reporting and presentation- interpretation and report writing- principles of thesis writing- format of reporting, oral presentation- seminars and conferences

Research proposals- research paper writing- publications and ethics- considerations in publishing, citation, plagiarism and intellectual property rights. Research methods- modelling and simulation- mathematical modeling- graphs- heuristic optimization- simulation modeling- measurement design- validity- reliability- scaling- sample design- data collection methods and data analysis

Expected Outcome

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

- Discuss research methodology concepts, research problems, research designs, thesis preparations, publications and research methods.
- Analyze and evaluate research works and to formulate a research problem to pursue research
- Prepare a thesis or a technical paper, and present or publish them
- Apply the various research methods followed in engineering research for formulation and design of own research problems and to utilize them in their research project.

References:

1. C. R. Kothari, Research Methodology, Methods and Techniques, New Age International Publishers, 2004.
2. R. Panneerselvam, Research Methodology, PHI Learning, 2014.
3. K. N. Krishnaswamy, AppaIyer Sivakumar, M. Mathirajan, Management Research Methodology, Integration of principles, Methods and Techniques, Pearson Education, 2006.
4. Deepak Chawla, Meena Sondhi, Research Methodology- concepts & cases, Vikas Publishing House, 2011.
5. J.W Bames, Statistical Analysis for Engineers and Scientists, McGraw Hill, New York
6. Schank Fr, Theories of Engineering Experiments, Tata McGraw Hill, 2008.
7. John W Best, James V Kahan, Research in Education, PHI Learning, 2010.
8. Sinha, S.C, Dhiman, A.K, Research Methodology, ESS Publications. (Vol. 1, 2), 2002.

COURSE PLAN			
Module	**Contents**	**Hours Allotted**	**Marks for Semester Exams**
I	**Overview of Research Methodology:** Research concepts- meaning-objectives- motivation-types of research-research process- criteria for good research- problems encountered by Indian researchers-scientific method- research design process- decisional.	**5**	**15 %**
II	**Research Problem and Design:** Formulation of research task- literature review-methods- primary and secondary sources- web as a source-browsing tools-formulation of research problems- exploration-hypothesis generation-problem solving approaches- introduction to TRIZ (TIPS) experimental research- principles-Laboratory experiment-experimental designs- ex post facto research- qualitative research.	**5**	**15 %**
First Internal Examination			
III	**Thesis writing, reporting and presentation:** Interpretation and report writing- techniques of interpretation- precautions in interpretation-significance of report writing- principles of thesis writing- format of reporting- different steps in report writing- layout and mechanics of research report- references- tables- figures- conclusions- oral presentation- preparation- making presentation- use of visual aids-effective communication- preparation for and presentation in seminars and conferences.	**4**	**15 %**
IV	**Research proposals, publications, ethics and IPR**: Research proposals-development and evaluation- research paper writing- layout of a research paper- journals in engineering- considerations in publishing-scientometry-impact factor- other indexing like h-index citations-open access publication- ethical issues- plagiarism- software for plagiarism checking- intellectual property right- patenting case studies.	**5**	**15 %**
Second Internal Examination			
V	**Research methods- Modelling and Simulation:** Modelling and Simulation- concepts of modelling- mathematical modelling- composite modelling- modelling with- ordinary differential equations- partial differential equations- graphs-heuristics and heuristic optimization-simulation modeling.	**5**	**20 %**
VI	**Research Methods- Measurement, sampling and Data acquisition:** Measurement design- errors- validity and reliability in measurement-scaling and scale construction- sample design- sample size determination- sampling errors- data collection procedures- sources of data- data collection methods- data preparation and data analysis	**4**	**20 %**

Internal continuous assessment: 40 Marks

Internal continuous assessment is in the form of periodical tests, assignments, seminars or a combination of all whichever suits best. There will be a minimum of two tests per subject. The assessment details are to be announced to students' right at the beginning of the semester by the teacher.

Semester Examination: 60 Marks

Course No.	Course Name	L-T-P	Credits	Year of Introduction
08ME6311	Advanced Mathematics and Optimization Techniques	3-0-0	3	2019

Course Objectives

The objective of this course is to introduce to the master students the basic ideas of linear algebra and optimization techniques and familiarise them with the necessary tools from these fields which have got diverse applications in applied sciences and engineering. The course provides a strong background on these areas which, besides being important for their applications, will also be essential for higher studies and research in engineering.

Syllabus

Vector spaces, linear transformation, inner products and orthogonality, Linear programming, simplex methods, integer programming, non-linear optimizations

Expected Outcome

On completion of the course, the students will have acquired knowledge and practical skills in the application of basic ideas of linear algebra such as vector spaces, linear transformations, orthogonality and approximations. They will also have learned the use of optimization techniques applicable to linear, non-linear and integer programming models in various fields of engineering.

References

1. Richard Bronson, Gabriel B Costa, Linear Algebra- An Introduction, Elsevier, 2nd Edition, 2009.
2. David C. Lay, Linear Algebra, Pearson Education, 4th Edition, 2012.
3. Ravindran, Philips, Solberg, Operations Research: Principles and Practice, Wiley, 2007.
4. Paneerselvam R, Operations Research, 2nd Edition, Prentice Hall of India, 2010.
5. Singiresu S Rao, Engineering Optimization Theory and Practice, 3rd Edition, New Age International Publishers, 2010.

	COURSE PLAN		
Module	**Contents**	**Hours**	**Marks for Semester Exams**
I	Vector spaces and examples, subspaces, linear independence and spanning sets, basis and dimension, co-ordinate representation of vectors	**7**	**15 %**
II	Linear transformations, matrix representation of linear transformations, properties-kernal and range, change of basis.	**7**	**15 %**
	First Internal Examination		
III	Inner product, length of vectors, orthogonal and orthonormal sets and basis, Gram-Schmidt orthogonolization, orthogonal projections, Least-square approximations. Singular value decomposition (All results without proof)	**7**	**15 %**
IV	Linear programming problems, formation of LPP, graphical method of solution-Simplex Method, Big M Method, Dual Simplex method	**7**	**15 %**
	Second Internal Examination		
V	Integer linear programming- Gomory's Cutting plane method, Branch and Bound method, mixed Integer Programming problems, zero-one programming	**7**	**20 %**
VI	Constrained non-linear Optimization-method of Lagrange multiplier, Kuhn Tucher conditions, Quadratic programming	**7**	**20 %**
	End Semester Examination		

Course No.	Course Name	L-T-P	Credits	Year of Introduction
08ME6321	**Robot Kinematics and Dynamics**	**3-1-0**	**4**	**2019**

Course Objectives

1. To familiarize students with robot classifications and configurations.
2. To acquaint the students with Forward Kinematics and Inverse Kinematics, Trajectory planning, dynamic modeling, control and applications of robots

Syllabus

Robot anatomy; Robot classifications; Robot specifications; Direct kinematics- the arm equation; Inverse Kinematics- solving the arm equation; Velocity analysis and statics of manipulators; Dynamics of manipulators; Workspace analysis and Trajectory planning;

Expected Outcome

Upon successful completion of this course, students will be able to:

1. Obtain kinematic model of a robotic manipulator
2. Develop dynamic model of a robotic manipulator
3. Plan a trajectory in joint space and Cartesian space
4. Do the forward and inverse kinematic analysis
5. To design a controller for a robotic manipulator

References

1. Robert. J. Schilling, Fundamentals of robotics- Analysis and control, Prentice Hall of India 1996.
2. R. K Mittal, I. J. Nagrath, Robotics and Control, Tata McGraw Hill, 2003.
3. John. J. Craig, Introduction to Robotics (Mechanics and control), Pearson Education Asia, 2002.
4. Ashitava Ghosal, Robotics-Fundamental concepts and analysis, Oxford University press.
5. John Iovine, PIC Robotics: A Beginner's Guide to Robotics Projects Using the PIC Micro, McGraw Hill.

COURSE PLAN			
Module	**Contents**	**Hours**	**Marks for Semester Exams**
I	Introduction- Definitions, Robot Elements- links, joints, end effector, actuators, sensors, hydraulic, pneumatic, electric drive systems, Robot specifications, Work envelope of different robots, Classification of Robots. Robot Coordinate Systems- Fundamental and composite rotations, homogeneous co-ordinates and transformations, Kinematic parameters, Direct Kinematics-The D-H representation.	**7**	**15 %**
II	The Arm equation-Kinematic analysis of a typical robot. The inverse kinematics problem- general properties of solutions, Inverse kinematics of a typical 3 DOF Robot. Linear and angular velocities of a rigid body; Manipulator Jacobian; linear an angular velocity of planar 3R manipulator.	**7**	**15 %**
	First Internal Examination		
III	Tool configuration vector, Workspace analysis, trajectory planning- steps in trajectory planning, joint space techniques, Cartesian space techniques, The pick and place operation-Continuous path motion, Tool configuration Jacobian matrix.	**10**	**15 %**
IV	Manipulator Dynamics- Lagrange equations, Dynamics of two link planar robot, Newton-Euler equations of rigid body, Lagrangian for open-chain robot, Dynamic model of a robot using Lagrange's Equation, 1 DOF and 2 DOF manipulator dynamic modelling, State space model of 1 DOF and 2 DOF manipulators, Constrained manipulators	**12**	**15 %**
	Second Internal Examination		
V	Redundant and parallel manipulators, stewart platform, Robot singularities, kinematics of redundant manipulators, differential kinematics of redundant manipulators.	**10**	**20 %**
VI	Robot End effectors: Classification of end effectors, Tools as end effector. Robot Applications: Material handling, Process, Assembly and Inspection application.	**10**	**20 %**
	End Semester Examination		

Course No.	Course Name	L-T-P	Credits	Year of Introduction
08ME6331	Advanced Control Systems	3-1-0	4	2019

Course Objectives

Acquaint the students with classical and modern control theory Familiarise the students with some real systems, which use automatic control Introduce to students with mathematical modeling of physical systems Introduce students to design of feedback control systems using classical and modern control theory.

Syllabus

Open loop and closed loop systems, Modelling of dynamic systems using transfer function, time domain and frequency domain analysis of dynamic systems, state space analysis, simple controllers for robotic manipulators.

Expected Outcome

Upon successful completion of this course, students will be able to:

1. Obtain transfer function or state space model of dynamic systems
2. Analyse a system using classical or modern control theory
3. Design simple controllers for a dynamic system

References:

1. Ogata K., Modern Control Engineering, Prentice Hall of India, New Delhi, 2010.
2. Nagarath I. J, Gopal M, Control System Engineering, Wiley Eastern, 2008.
3. Dorf R.C, R.H. Bishop, Modern Control Systems, Pearson Education, 2011
4. Nise N. S, Control Systems Engineering, 6th Edition, Wiley Eastern, 2010.
5. Ogata K., System Dynamics, Prentice Hall of India, New Delhi, 2008

COURSE PLAN			
Module	**Contents**	**Hours Allotted**	**Marks for Semester Exams**
I	Review of system concepts, linear, non- linear, static, dynamic, time variant and time invariant, continuous time and discrete time, distributed and lumped parameter systems. Open loop and closed loop systems. Transfer function-T.F of simple- Mechanical and Electromechanical systems; block diagram representation- block diagram reduction- signal flow graph- Mason's gain formula-characteristics equation.	**7**	**15 %**
II	Time domain analysis of control systems: Transient and steady state responses-test signals- time domain specifications- first and second order systems- impulse and step responses- steady state error analysis-static error coefficient of type 0,1,2 systems- Dynamic error coefficients	**6**	**15 %**
First Internal Examination			
III	Concept of stability: stability of feedback system- Routh's stability criterion- Root locus based analysis- Frequency domain analysis: Introduction- Bode plot- Frequency domain specifications: stability analysis using Bode plot.	**10**	**15 %**
IV	State space analysis of systems: Introduction to state concept- state equation of linear continuous time systems, matrix representation of state equations. Phase variable and canonical forms of state representation	**12**	**15 %**
Second Internal Examination			
V	Solution of time invariant autonomous systems- state transition matrix-relationship between state equations and transfer function. Properties of state transition matrix- controllability & observability. State feedback design via pole placement technique.	**10**	**20 %**
VI	Design and implementation of PID controllers. PID control of single link manipulator, digital control of single link manipulator, PID control of multilink manipulator, model based control, force control of a single mass, partitioning a task for force and position control..	**11**	**20 %**
End Semester Examination			

Course No.	Course Name	L-T-P	Credits	Year of Introduction
08ME6341	Measurements and Sensors for Automation	3-0-0	3	2019

Course Objectives

The objective of this course is to provide the basic understanding about operational characteristics and applications of various sensors, transducers, measurements and instrumentation.

Syllabus

Introduction to Measurement, Testing & Calibration, Introduction to Sensors, Displacement Measurement, Pressure Measurement, Temperature Measurement, Flow Measurement, Level Measurement, Magnetic sensors, Radiation sensors, Feedback transducer system, Advancement in Sensor technology, MEMS, Nano Sensors, Sensor Signal Conditioning

Expected Outcome

On completion of the course, the students will have acquired knowledge and skills in using sensors with conditioning circuits for automation systems which has applications in diverse areas of process and manufacturing automation.

References

1. K.L. Kishore, Electronic Measurement and Instrumentation, Pearson.
2. D. Patranabis, Sensors and Transducers, PHI Learning Pvt. Ltd., 2nd Edition
3. A. K. Ghosh, Introduction to Measurements and Instrumentation, 4th Edition, PHI.
4. D V S Murty, Transducers and Instrumentation, PHI Learning Pvt. Ltd.
5. B. C. Nakra, K. K. Chaudhry, Instrumentation, Measurement and Analysis, 4th Edition, Tata McGraw Hill.
6. W. D. Cooper, Modern Electronics Instrumentation & Measurement Techniques, PHI.
7. John. P. Bentley, Principles of Measurement Systems, Pearson
8. E. O. Doebelin, Dhanesh N Manik, Measurement Systems, 6th Edition, McGraw Hill.
9. Bolton W, Mechatronics- Electronic Control Systems in Mechanical & Electrical Engineering, 2nd Edition, Longman Publishers, 2002.

	COURSE PLAN		
Module	**Contents**	**Hours Allotted**	**Marks for Semester Exams**
I	**Introduction to Measurement:** Significance of measurement, Different methods of measurement, Classification of measuring instruments, Application of measurement systems, typical measurement schemes. **Units and Standards:** MKS, SI units of engineering parameters, Details of different standards- mass, length, time, frequency, temperature, EMF, ampere, sub standards and lab standards.	**3**	**15 %**
	Performance Characteristics: Definition of range, span, accuracy, precision, drift, sensitivity, reproducibility, repeatability, dead zone, resolution, hysteresis, threshold, zero error, noise, linearity, loading effect, static characteristics.	**3**	
II	**Dynamic Characteristics:** Dynamic response; Transient response; speed of response, fidelity, measuring lag etc, Linear approximation, Introduction to compensation techniques. Significance of testing and calibration, Calibration curve, Standards for calibration, Different calibration procedures-primary, secondary, direct, indirect, routine calibration, Calibration setup: pressure gauge, level etc.	**7**	**15 %**
First Internal Examination			
III	**Introduction to Sensors:** Definition and differences of sensors and transducers, Classification, static and dynamic characteristics, electrical characterization, mechanical and thermal characterization including bath-tub curve. **Introduction to Transducers:** Transducer classification, Active and Passive Transducers, Potentiometric Transducers, Linear and non-linear potentiometer, Feedback transducer system**,** Inverse transducer, Self-balancing transducer, Servo- operated manometer, Feedback pneumatic load cell, integrating servo. **Displacement Measurement:** Linear /Angular displacement, Pneumatic/ Electric/ Optical/ Ultrasonic/Electronic Displacement Transducers, Tactile and Proximity Sensors, Typical application schemes, Tacho generators.	**7**	**15 %**
IV	**Pressure Measurement:** Pressure Units, Force Summing Devices, Secondary Transducers, Vacuum Measurement, Torque Measurement, Resistance/Bonded Type Strain Gauge. **Temperature Measurement:** Electric Method, Change in Electrical Properties, RTD, Thermocouples, Thermistors, Thermowells. nuclear thermometers, resistance change type thermometric sensors. **Flow Measurement:** Reynold Number, Head type flowmeters, Velocity measurement type flowmeters, Mass flow measurement type flow meters.	**7**	**15 %**
Second Internal Examination			
V	**Level Measurements:** Importance, advantage and limitation of different instruments, visual level indicators, float type, Purge method of measuring level, Buoyancy method, Resistance and capacitance probes for level measurement, limit switches, level measurement in pressurized vessels, solid level measurement techniques **Magnetic sensors:** Basic working principles, Magnetostrictive, Hall effect, Eddy current type. Radiation sensors: Photo-detectors, Photo-emissive, photomultiplier, scintillation detectors. **Electroanalytical sensors:** Electrochemical cell, SHE, Polarization, Reference electrode, Metal electrodes, Membrane electrodes, Electroceramics	**7**	**20 %**

VI	**Advancement in Sensor technology:** Introduction to smart sensors, Film sensors, Introduction to semiconductor IC technology and Micro Electro Mechanical System (MEMS), Nano-sensors, Bio-Sensors and vision sensors. **Sensor Signal Conditioning:** Amplification/Attenuation using Op- Amp, Filtering, Protection from high current/Voltage, Wheatstone bridge, ac bridge, Comparator, Analog to digital conversion, Digital to Analog Conversion	**8**	**20 %**
End Semester Examination			

Course No.	Course Name	L-T-P	Credits	Year of Introduction
08ME6351(A)	Advanced Mechanisms	3-0-0	3	2019

Course Objectives

1. To develop student understanding of the theoretical background for basic and advanced kinematics and synthesis of mechanisms to achieve desired motion with different methods optimal synthesis of mechanism, and synthesis of spatial mechanism along with application
2. To introduce students to basic and advanced computer-based tools for analysis and synthesis of mechanisms.

Syllabus

Analysis of planar and spatial mechanisms: path curvature theory synthesis of planar mechanisms, graphical synthesis of planar mechanisms, path generation, function generation and rigid body guidance Analytical synthesis of planar mechanisms, Freudenstein's equation Introduction to multi-body dynamics-generalized matrix formulation.

Expected Outcome

After learning the course the students should be able to:

1. Understand various methods of synthesis, optimization of synthesis, graphical and analytical methods of synthesis.
2. Become familiar with basic and advanced tools for the analysis and design of linkages.

References

1. J. Hirschhorn, Kinematics and dynamics of plane mechanisms, McGraw-Hill, 1962.
2. J.J Uicker, G.R Pennock, J.E Shigley, Theory of Machines and Mechanisms, Oxford University Press, 2005.
3. A. Ghosh, A. K Mallik Theory of mechanisms and machines, E.W.P Publishers. Delhi, 1999.
4. Allen S. Hall Jr., Kinematics and linkage design, PHI, 1964.
5. C. Wilson, Kinematics and dynamics of machinery, Pearson, 3rd Edition.
6. P.E. Nikravesh, Computer aided analysis of mechanical systems, PHI Publications.
7. A. Erdman, G. Sandor, S. Kota, Mechanism design analysis and synthesis, Vol. 1, 4th Edition, 2001, Prentice Hall.
8. G.N Sandor, A.G. Erdman, Advanced mechanism design: Analysis and synthesis, Prentice Hall, 1984.
9. J. Hannah, R.C. Stephens, E. Arnold, Mechanics of machines: Advanced theory and examples, 2nd Edition.
10. Hartenberg, R.S, Denavit, Jacques, Kinematic synthesis of linkages, McGrawHill..
11. R.L. Norton, Design of Machinery, Tata McGraw Hill, 2005.
12. V Ramamurti, Mechanics of Machines, Narosa, 2005.

	COURSE PLAN		
Module	**Course description**	**Hours**	**Marks for Semester Exams**
I	Introduction to plane motion, The Inflection circle, Euler-Savary equation, analytical and graphical determination of d_i, Bobillier's construction, collineation axis, Hartmann's construction, cubic of stationary curvature, Inflection circle for the relative motion of two moving planes, application of the inflection circle to kinematic analysis.	**7**	**15 %**
II	Polode curvature, Hall's Equation, Polode curvature in the four bar mechanism, coupler motion, relative motion of the output and input links, determination of the output angular acceleration and its rate of change, Freudenstein's collineation-axis theorem, Carter-Hall circle, The circling-point curve for the Coupler of a four bar mechanism.	**7**	**15 %**
	First Internal Examination		
III	The four bar linkage, guiding a body through two distinct positions, guiding a body through three distinct positions, The Roto center triangle, guiding a body through four distinct positions, Burmester's curve. special cases of four position synthesis-Finite Ball's point-five positions-cognate linkages, geared five bar and parallelogram six bar cognates, six bar parallel motion generator	**7**	**15 %**
IV	Coupler curve synthesis: design of six bar mechanisms for different applications including dwell. Algebraic methods-using vector loop equations and complex algebra, synthesis of multi loop linkage mechanisms, geared linkages, application of instant centre in linkage design. Practical considerations in mechanism design, mechanism defects.	**7**	**15 %**
	Second Internal Examination		
V	Kinematics of Spatial Mechanisms and Robotics: Introduction, topology arrangements of robotics arms, Kinematic analysis of spatial RSSR mechanism, Denavit-Hartenberg parameters, Forward and inverse kinematics of robotic manipulators. Study and use of Mechanism using Simulation Software packages.	**7**	**20 %**
VI	Function generation: General discussion, function generation: relative-roto center method, overlay's method, function generation-velocity-pole method, path generation: Hrones's and Nelson's motion Atlas, Roberts's theorem. Freudenstien's equation, precision point approximation, precision-derivative approximation Path Generation: Synthesis of four-bar mechanisms for specified instantaneous condition, method of components, synthesis of four-bar mechanisms for prescribed extreme values of the angular velocity of driven link, method of components.	**7**	**20 %**
	End Semester Examination		

Course No.	Course Name	L-T-P	Credits	Year of Introduction
08ME6351(B)	Fluid Power Automation	3-0-0	3	2019

Course Objectives

The objective of this course is to reinforce basic ideas of fluid power automation. The basic building blocks of pneumatic and hydraulic automation systems will be dealt with in detail and enable the students to design and optimise pneumatic and hydraulic automation schemes.

Syllabus

Classification of drives, Drive characteristics, Direction, flow and pressure control valves, Electro hydraulic servo valves, Typical Design methods- sequencing circuits design, Electrical control of pneumatic and hydraulic circuits, Proportional control of hydraulic systems.

Expected Outcome

On completion of the course, the students will have acquired knowledge and practical skills in the modelling and optimization of hydraulic and pneumatic systems which has applications in diverse areas of process and manufacturing automation.

References

1. Peter Rohner, Fluid Power Logic Circuit Design, Mcmelan Prem, 1994.
2. Antony Esposito, Fluid Power Systems and control Prentice-Hall,1988
3. E.C.Fitch, J.B.Suryaatmadyn, Introduction to fluid logic, McGraw Hill, 1978
4. Peter Rohner, Fluid Power logic circuit design. The Macmillan Press Ltd., London, 1979
5. Herbert R. Merritt, Hydraulic control systems, John Wiley & Sons, New York, 1967
6. Dudbey. A. Peace, Basic Fluid Power, Prentice Hall Inc, 1967.

COURSE PLAN			
Module	**Contents**	**Hours Allotted**	**Marks for Semester Exams**
I	Fluid power system generation and actuators: Need for automation, Classification of drives, hydraulic, pneumatic and electric, comparison, ISO/ANSI symbols for their elements, selection criteria. Generating Elements, Hydraulic pumps and motor gears, vane, piston pumps, motors, selection and specification, Drive characteristics, Utilizing Elements, Linear actuator, Types, mounting details, cushioning, power packs, accumulators	**7**	**15 %**
II	Introduction to Pneumatic Systems: Basic Requirements for Pneumatic System, Applications,Pneumaticfundamentals,Construction,workingprincipleand operation of pneumatic power transmission system components like Power source, FRL unit, Actuators and control valves like DCV, FCV, PCV, time delay, quick exhaust, twin pressure, shuttle. Pneumatic circuits: Basic pneumatic circuits, Development of single Actuator Circuits, Development of multiple Actuator Circuits, Cascade method for sequencing.	**6**	**15 %**
First Internal Examination			
III	Control and regulation elements: Control and regulation elements, direction, flow and pressure control valves, methods of actuation, types, sizing of ports. spool valves, operating characteristics, electro hydraulic servo valves, different types, characteristics and performance.	**6**	**15 %**
IV	Method of control: Comparison between analogue and digital control, Proportional attributes, Ramp, Gain, dead band, Dither, Pulse width modulation, Amplifier cards, Principles of operation, Design and application, Analogue and digital, Closed loop, Internal and external feedback devices, Operationandapplicationofclosedloopsystem,Integratedelectronicsoption frequency Response, principles of operation, Bode diagrams and their use in manufacturer's data, PID control, Practical exercises, Commissioning and set up procedures, open loop circuits, closed loop circuits, Interface to the control.	**7**	**15 %**
Second Internal Examination			
V	Electrical control of pneumatic and hydraulic circuits-use of relays, timers, counters, Programmable logic control of hydraulic and pneumatic circuits, PLC ladder diagram for various circuits, motion controllers, use of field busses in circuits. Electronic circuits for various open loop control and closed loop(Servo) control of hydraulics and pneumatics. Circuit design for hydraulic and pneumatics: Typical design methods-sequencing circuits design, combinational logic circuit design, cascade method, truth table, Karnaugh map method, fluid logic controls systems: Principles of fluid logic control, basic fluidic devices, fluidic sensors, fluidic logic circuits.	**8**	**20 %**
VI	Application of Propositional and Servo Valves: Velocity control, Position control and Directional control and applications example: paper industry, process industry, printing sawmill, woodworking, extrusion press, power metallurgical press, continuous casting, Food and packaging, Injection moulding, Solar energy and automobile.	**8**	**20 %**
End Semester Examination			

Course No.	Course Name	L-T-P	Credits	Year of Introduction
08ME6351(C)	**Additive Manufacturing**	**3-0-0**	**3**	**2019**

Course Objectives

This course enables the students to:
1. Exploit technology used in additive manufacturing.
2. Understand importance of additive manufacturing in advance manufacturing process.
3. Acquire knowledge, techniques and skills to select relevant additive manufacturing process.
4. Explore the potential of additive manufacturing in different industrial sectors.
5. Apply 3D printing technology for additive manufacturing.

Syllabus

Additive manufacture: basic principle, processes, Machines and Systems, Pre-Processing and post-processing, Applications of additive manufacturing in rapid prototyping, rapid manufacturing, rapid tooling, repairing and coating.

Expected Outcome

After the completion of this course, students will be:
1. Able to define the various process used in Additive Manufacturing
2. Able to analyse and select suitable process and materials used in Additive Manufacturing.
3. Able to identify, analyse and solve problems related to Additive Manufacturing.
4. Able to apply knowledge of additive manufacturing for various real-life applications
5. Able to apply technique of CAD and reverse engineering for geometry transformation in additive manufacturing.

Text books:

1. Gibson I, Rosen D W, Stucker B, Additive Manufacturing Methodologies: Rapid Prototyping to Direct Digital Manufacturing, Springer, 2010.
2. Chua C. K, Leong K.F, Lim C.S, Rapid prototyping: Principles and applications, 3rd Edition, World Scientific Publishers, 2010.
3.Chee Kai Chua, Kah Fai Leong, 3D Printing and Additive Manufacturing: Principles and Applications: 4th Edition of Rapid Prototyping, World Scientific Publishers, 2014.
4. Gebhardt A., Rapid prototyping, Hanser Gardener Publications, 2003.

Reference books:

1. Liou L.W, Liou F.W, Rapid Prototyping and Engineering applications: A tool box for prototype development, CRC Press, 2007.
2. Kamrani A.K, Nasr E.A., Rapid Prototyping: Theory and practice, Springer, 2006.
3. Mahamood R.M, Laser Metal Deposition Process of Metals, Alloys, and Composite Materials, Engineering Materials and Processes, Springer, 2018
4. Ehsan Toyserkani, Amir Khajepour, Stephen F. Corbin, Laser Cladding, CRC Press, 2004.

COURSE PLAN			
Module	**Contents**	**Hours Allotted**	**Marks for Semester Exams**
I	Introduction: Overview, Basic principle need and advantages of additive manufacturing, Procedure of product development in additive manufacturing, Classification of additive manufacturing processes, Materials used in additive manufacturing, Challenges in Additive Manufacturing.	**6**	**15 %**
II	Additive Manufacturing Processes: Z-Corporation 3D-printing, Stereolithography apparatus (SLA), Fused deposition modeling (FDM), Laminated Object Manufacturing(LOM), Selective deposition lamination (SDL), Ultrasonic consolidation, Selective laser sintering (SLS), Laser engineered net shaping (LENS)	**7**	**15 %**
First Internal Examination			
III	Electron beam free form fabrication (EBFFF), Electron beam melting (EBM), Plasma transferred arc additive manufacturing (PTAAM), Tungsten inert gas additive manufacturing (TIGAM), Metal inert gas additive manufacturing (MIGAM).	**7**	**15 %**
IV	Additive Manufacturing Machines and Systems: Axes, Linear motion guide ways, Ball screws, Motors, Bearings, Encoders/ Glass scales, Process Chamber, Safety interlocks, Sensors. Introduction to NC/CNC/DNC machine tools, CNC programming and introduction, Hardware Interpolators, Software Interpolators, Recent developments of CNC systems for additive manufacturing.	**7**	**15 %**
Second Internal Examination			
V	Pre-Processing in Additive Manufacturing: Preparationof3D-CADmodel, Reverse engineering, Reconstruction of 3D-CAD model using reverse engineering, Part orientation and support generation, STL Conversion, STL error diagnostics, Slicing and Generation of codes for tool path, Surface preparation of materials.	**7**	**20 %**
VI	Post-Processing in Additive Manufacturing: Support material removal, surface texture improvement, accuracy improvement, aesthetic improvement, preparation for use as a pattern, property enhancements using non-thermal and thermal techniques, Brief information on characterization techniques used in additive manufacturing, Applications of additive manufacturing in rapid prototyping, rapid manufacturing, rapid tooling, repairing and coating, Future scope in Additive Manufacturing. Modelling and Simulation: Thermal model to predict size of deposition such as width and height of deposition, Finite element simulation of additive process.	**8**	**20 %**
End Semester Examination			

Course No.	Course Name	L-T-P	Credits	Year of Introduction
08ME6351(D)	Mechatronics Systems and Applications	3-0-0	3	2019

Course Objectives

1. Be able to integrate mechanical, electronics, control and computer engineering in the design of mechatronics systems.
2. Be able to do the complete design, building, interfacing and actuation of a mechatronic system for a set of specifications.

Syllabus

Mechatronics in manufacturing, Sensors and Transducers, selection of sensors, Mechanical and electrical actuation systems, microprocessors, microcontrollers, PLC, modelling and simulation of mechanical and electrical systems, simulation of electromechanical systems, simulation and simulation tools, models for mechanical and electromagnetic actuators, hardware in loop simulation

Expected Outcome

1. Be proficient in the use of LabVIEW software for data acquisition.
2. Be proficient in the modelling and simulation of mechatronics systems

Text Books:

1. W.Bolton, Mechatronics, Pearson education, 2nd Edition, 2003.
2. R.K Rajput, A textbook of mechatronics, S. Chand & Co, 2007.
3. Michael B.Histand, David G. Alciatore, Introduction to Mechatronics and Measurement Systems, McGraw-Hill, 2000.
4. Nitaigour Premchand Mahadik, Mechatronics, Tata McGraw-Hill, 2003.
5. Lawrence J. Kamm, Understanding Electro-Mechanical Engineering, An Introduction to Mechatronics, Prentice Hall of India, 2000

Reference Books:

1. D. A. Bradley, Dawson D, Buru N.C, Loader A. J, Mechatronics, Chapman and Hall, 1993.
2. Dan Necsulesu, Mechatronics, Pearson Education Asia, 2002.
3. V. Giurgiutiu, S. E. Lyshevski, Micromechatronics, Modeling, Analysis, and Design with MATLAB, 2nd Edition, CRC Press, 2009.
4. A. Smaili, F. Mrad, Mechatronics- Integrated technologies for intelligent machines, Oxford University press, 2008.
5. D.C. Karnopp, D.L. Margolis, R.C. Rosenberg, System Dynamics: A Unified Approach, 2nd Edition, Wiley-Interscience, 1990.
6. L. Ljung, T. Glad, Modeling of Dynamical Systems, Prentice Hall, 1994.
7. G. Gordon, System Simulation, 2nd Edition, PHI Learning, 2009.

COURSE PLAN			
Module	**Contents**	**Hours Allotted**	**Marks for Semester Exams**
I	Introduction: Introduction to Mechatronics system, mechatronics in manufacturing, product and design, Measurement Systems, Control System, comparison between traditional and mechatronics approach. Sensors and Transducers: Introduction, Performance terminology, Displacement, Position and Proximity, Velocity and motion, Fluid pressure, Temperature sensors, Light sensors, Selection of sensors.	**6**	**15 %**
II	Mechanical Actuation System: Cams, Gear trains, Ratchet and Pawl, Belt and chain drives, Bearings. Hydraulic and Pneumatic Actuation System: Introduction to Hydraulic and Pneumatic Systems, Directional Control valves, Flow control valves. Electrical Actuation System: Electrical systems, Solid State Switches, Solenoids, D.C. motors, A.C. motors, Stepper motors.	**7**	**15 %**
First Internal Examination			
III	Processors/Controllers: Microprocessors: Microprocessor systems, Microcontrollers, applications. Programmable Logic Controllers: Basic PLC structure, Input/output processing, ladder programming, latching and internal relays, Sequencing, Timers and counters, Shift registers, Master and jump controls, Code conversion, Data handling, selection of PLC.	**7**	**15 %**
IV	Physical Modelling: Mechanical and electrical systems, physical laws, continuity equations, compatibility equations, system engineering concept, system modelling with structured analysis, modelling paradigms for mechatronic system, block diagrams, mathematical models, systems of differential-algebraic equations, response analysis of electrical systems, thermal systems, fluid systems, mechanical rotational system, electrical-mechanical coupling. Case studies of mechatronics system: Pick and place robots, automated guided vehicle, Automatic car park barrier, Engine management system.	**7**	**15 %**
Second Internal Examination			
V	Simulation Techniques: Solution of model equations and their interpretation, zeroth, first and second order system, solution of 2^{nd} order electro-mechanical equation by finite element method, transfer function and frequency response, non-parametric methods, transient, correlation, frequency, Fourier and spectra analysis, design of identification experiments, choice of model structure, scaling, numeric methods, validation, methods of lumped element simulation.	**7**	**20 %**
VI	Modelling of sensors and actuators, hardware in the loop simulation (HIL), rapid controller prototyping, coupling of simulation tools, simulation of systems in software (MATLAB, LabVIEW) environment. Modelling and Simulation of Practical Problems: Pure mechanical models, Models for electromagnetic actuators including the electrical drivers, Models for DC-engines with different closed loop controllers using operational amplifiers, Models for vehicle systems.	**8**	**20 %**
End Semester Examination			

Course No.	Course Name	L-T-P	Credits	Year of Introduction
08ME6351(E)	Emerging Smart Materials for Mechatronics Applications	3-0-0	3	2019

Course Objectives

The objective of this course is to give students an introduction to the fundamentals of smart materials, their fundamental characteristics, operating principals and physical properties. It will also provide a foundation for the design of sensors and actuators from smart materials, evaluate their advantages and limitations.

Syllabus

Overview of smart materials, Piezoelectric Ceramics, Piezo-polymers, Magnetostrictive Materials, Electroactive Polymers, Shape Memory Alloys, Electro and Magneto Rheological Fluids, Modelling of smart materials, introduction to composite smart materials, Mechanics of smart composite materials, Smart sensors based on high bandwidth low strain smart materials, Low-bandwidth high strain smart actuators, Micro-electro mechanical Smart Systems, Intelligent devices based on smart materials, Applications of Smart Actuators: Active and Hybrid Vibration Control, Active Shape Control, Distributed Sensing and Control of Smart Beams.

Expected Outcome

1. Understand the characteristics of smart materials and their applications.
2. Evaluate Piezoelectric, Shape memory alloys, Electro-active polymers, Electro-rheological fluids, Magneto Rhelological Fluids and Magnetostrictive materials for various mechanical systems.
5. Evaluate the application of smart materials in the development of actuators.

Text books:

1. Jose L. Pons, Emerging Actuator Technologies, a Micromechatronics Approach, John Wiley & Sons Ltd, 2005.
2. Ralph Smith, Smart Material Systems: Model Development, SIAM, Society for Industrial and Applied Mathematics, 2005.
3. F. Carpi, D. De Rossi, R. Kornbluh, R. Pelrine, P. Sommer-Larsen, Dielectric Elastomers as Electromechanical Transducers, Elsevier, Hungry, 2008..
4. Y. B. Cohen, Electroactive Polymer (EAP) Actuators as Artificial Muscles Reality, Potential and Challenges, SPIE press, USA, 2004.
5. Brian Culshaw, Smart Structures and Materials, Artech House, 2000.
6. Gauenzi, P, Smart Structures, Wiley, 2009.
7. Cady, W. G., Piezoelectricity, Dover Publications.

COURSE PLAN			
Module	**Contents**	**Hours Allotted**	**Marks for Semester Exams**
I	Introduction: Smart materials and their application for sensing and actuation, Mechatronics aspects.	**6**	**15 %**
II	Piezoelectric materials: Piezoelectricity and piezoelectric materials, Constitutive equations of piezoelectric materials, Perovskyte Piezoceramic Materials, Single Crystals vs Polycrystalline Systems, Piezoelectric Polymers, Piezoelectric actuator types, Control of piezoelectric actuators, Applications of piezoelectric actuators for precise positioning and scanning.	**7**	**15 %**
First Internal Examination			
III	Shape memory alloys (SMA): Properties of shape memory alloys, Shape memory effects, Pseudo-elasticity in SMA, Design of shape memory actuator, selection of materials, Smart actuation and control, Shape Memory Polymers, Applications of SMA in precision equipments for automobiles, trains and medical devices.	**6**	**15 %**
IV	Electro-active polymers (EAPs): Ionic polymer metal composites (IPMC), Conductive polymers, Carbon nanotubes, Dielectric elastomers, Design & control issues for EAP actuators, Electro-rheological Fluids, Magneto Rhelological Fluids, Applications of EAP for biomemetic, tactile display and medical devices.	**8**	**15 %**
Second Internal Examination			
V	Magnetostrictive materials: Basics of magnetic properties of materials, magnetostriction: constitutive equations, types of magnetostrictive materials, Rare earth Magnetostrictive materials, Design & control of magnetostrictive actuators,	**7**	**20 %**
VI	Giant Magnetostriction and Magneto-resistance Effect, Applications of magnetostrictive materials for active vibration control. Summary, conclusion and future outlook: Comparative analysis of different smart materials based actuators, Future research trend and applications trends of smart materials and smart materials based actuator technology.	**8**	**20 %**
End Semester Examination			

Course No.	Course Name	L-T-P	Credits	Year of Introduction
08ME6361	Seminar I	0-0-2	2	2019

Course Objectives

To improve debating capability of the student to present a technical topic.
To improve communication and presentation skills of the student.

Course Details

Individual students are required to choose a topic of their interest, in consultation with any faculty member offering courses for the programme. The topic should be related to Industrial automation and Robotics, preferably from outside the M. Tech syllabus. The topic should be based on a journal/conference publication within a span of last 3 years. The duration of the seminar should be limited to 40 minutes with a 10 minute question answer session. A committee with the Head of the department as the Chairman and two faculty members including the PG coordinator shall evaluate the seminar based on the coverage of the topic, presentation style and ability to answer the questions put forward by the committee. Each student shall submit two copies of a write up on the topic. One copy certified by the Chairman shall be returned to the student and the other will be kept in the departmental library.

Expected Outcome

Upon successful completion of the seminar, the student should be able to:

1. Get good exposure in the current research and developments in the specific stream.
2. Improve the writing and presentation skills.
3. Explore domains of interest so as to pursue the PG research project

08ME6361 Seminar I (L-P-T:0-2-0): 2 Credits

A committee with the Head of the department as the Chairman and two faculty members from the department as members shall evaluate the seminar based on the coverage of the topic, presentation and ability to answer the questions put forward by the committee.

Internal Continuous Assessment (Maximum Marks-100)

Assessment Procedure	Weightage (%)
Topic coverage and presentation	50
Answering ability	20
Report	30

Course No.	Course Name	L-T-P	Credits	Year of Introduction
08ME6371	Automation Lab	0-0-2	1	2019

Course Prerequisites

Basic knowledge of electrical circuits and components like relays, timers, proximity sensors, etc.

Course Objectives

This laboratory aims to introduce the various elements of automation namely actuators and sensors. It also enable the students to plan, design and optimise logic circuits using these basic elements.

Expected Outcome

After completing the laboratory, the students will be able to design and build automation logic circuits using the basic elements

List of Experiments

1. Programmable Logic Controller Experiments
   Speed control of ac servo motor using PLC, Lift control system using PLC, Water level control using PLC
2. Exercises on Hydraulic circuits.
3. Robot Programming Experiments
4. Experiments on CNC Programming Simulator (Turning and Milling)
5. Experiments on CNC Programming (Turning or Milling)
6. Usage of DCVs in hydraulic logic.
7. Experiments on electro-hydraulics.
8. Exercises on pneumatic circuits.
9. Cylinder sequencing using pneumatic circuits.
10. Experiments on Electro pneumatics.
11. Simulation of Pneumatic and Hydraulic Circuits using Automation Studio Software.
12. Experiments using Sensors.
13. Calibration of Proximity sensors
14. State Space Modeling of DC motor in MATLAB and LabVIEW.
15. PID Controller based speed control of DC motor in LabVIEW.

08ME6371 Automation Lab (L-T-P: 0-0-2) Credits: 1	
Internal Continuous Assessment (Maximum Marks-100)	
Assessment Procedure	Weightage (%)
Practical Records/outputs (Continuous evaluation)	50
Final Test (Experiments)	30
Final Viva-Voce	20