PROPOSED COURSE STRUCTURE AND SYLLABUS

M. Tech. Automation and Robotics

DEPARTMENT OF MECHANICAL ENGINEERING
DR. BABASAHEB AMBEDKAR TECHNOLOGICAL UNIVERSITY
LONERE 402 103

DIST – RAIGAD, MAHARASHTRA, INDIA

Vision

The vision of the Department is to achieve excellence in teaching, learning, research and transfer of technology and overall development of students.

Mission

Imparting quality education, looking after the holistic development of students and conducting need-based research and extension activities.

Post Graduate Attributes

The Post Graduate Attributes are the knowledge skills and attitudes which the students have at the time of post-graduation. These Post Graduate Attributes identified by National Board of Accreditation are as follows:

1. **Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of engineering problems involving research.
2. **Problem analysis:** Identity, formulate, research literature, and analyses complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. **Design/development of solutions:** Design solutions for engineering problems involving research and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4. **Conduct investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5. **Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to research activities with an understanding of the limitations.
6. **The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
7. **Environment and sustainability:** Understand the impact of the research based engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8. **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice to research problems.
9. **Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10. **Communication:** Communicate effectively on complex engineering activities with the Engineering community and with society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

11. **Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader of a team, to manage projects and in multidisciplinary environments.
12. **Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Educational Objectives

PEO1	To train students with in-depth and advanced knowledge to become professional and capable of identifying, analyzing and solving complex problems in the areasof Robotics and Automation.
PEO2	To enable post graduates to carry out innovative and independent research work, disseminate the knowledge in Academia/Industry/Research Organizations todevelop systems and processes in the related field.
PEO3	To prepare the students to exhibit a high level of professionalism, integrity, effective communication skills and environmental and social responsibility.
PEO4	To provide an academic environment that gives adequate opportunity to the students to cultivate life-long independent learning ability for their successful professional career.

Program Outcomes

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

PO1	Acquire, demonstrate and apply advanced knowledge in the area of Robotics and Automation.
PO2	Identify problems in the field of Robotics and Automation, formulate them and solve by using advanced techniques.
PO3	Conduct independent research and generate new knowledge for the benefit of community, society Industry and country.
PO4	Apply various numerical methods, advanced software and engineering tools to model, analyze and solve Robotics and Automation engineering.
PO5	Work effectively in interdisciplinary teams for solving real life problems in the related field.
PO6	Apply engineering and scientific principles for the effective management of Robotics and Automation.
PO7	Effectively communicate through technical reports, presentations and scientific publications with the engineering community as well as society at large.
PO8	Demonstrate traits of management in handling engineering projects, related finance, and coordinate with workforce towards achieving goals.
PO9	Demonstrate high level of professional and intellectual integrity, ethics of research and scholarly standards.
PO10	Examine critically the outcomes of one's actions and make corrective measures subsequently.
PO11	Demonstrate the ability to work in team in the laboratory in achieving multidisciplinary tasks required for the project.
PO12	Engage in life-long reflective and independent learning with high level of enthusiasm and commitment.

Department of Mechanical Engineering
Master of Technology
(Automation & Robotics)

Syllabus effective from July 2021

Semester-I

Subject Code	Subject	Teaching Scheme				Examination Scheme				
		L	T	P	C	CA	MSE	ESE	OR	Total
ME-AR101	Mechatronics	03	1	--	04	20	20	60	--	100
ME-AR102	Industrial Hydraulics & Pneumatics	03	1	--	04	20	20	60	--	100
ME-AR103	Industrial Automation	03	1	--	04	20	20	60	--	100
ME-AR104	Elective-I	03	--	--	03	20	20	60	--	100
ME-AR105	Elective-II	03	--	-	03	20	20	60	--	100
BSH16	Communication Skills	02	--	-	02	25	--	--	25	50
ME-AR107	Automation & Robotics Lab	--	--	03	02	25	--	--	25	50
		17	**03**	**03**	**22**	**150**	**100**	**300**	**50**	**600**

List of Elective Subjects

Elective I - Semester I

Sr. No.	Subject Code	Subject Name
01.	ME-AR104A	Concepts of Mechanical Elements*
02.	ME-AR104B	Concepts of Electronics & Electrical Elements#

* For students with Electronics/Electrical/Computer Engineering and related background.

\# For students with Mechanical Engineering and related background.

Elective II - Semester I

Sr. No.	Subject Code	Subject Name
01.	ME-AR105A	Metrology and Computer Aided Inspection
02.	ME-AR105B	Product Design & Development
03.	ME-AR105C	Design of Mechanism and Manipulator
04.	ME-AR105D	Artificial Intelligence & Expert System in Automation

Semester-II

Subject Code	Subject	Teaching Scheme				Examination Scheme				
		L	T	P	C	CA	MSE	ESE	OR	Total
ME-AR201	Industrial Robotics	03	1	--	04	20	20	60	--	100
ME-AR202	Drives and Control System for Automation	03	1	--	04	20	20	60	--	100
ME-AR203	Elective-III	03	--	--	03	20	20	60	--	100
ME-AR204	Elective- IV	03	--	--	03	20	20	60	--	100
ME-AR205	Open Elective I	03	--	--	03	20	20	60	--	100
ME-AR206	Mini Project	--	--	04	02	50	--	--	50	100
ME-AR207	Seminar-I	--	--	04	02	50	--	--	50	100
		15	**02**	**08**	**21**	**200**	**100**	**300**	**100**	**700**

List of Elective Subjects

Elective (III) - Semester II

Sr. No.	Subject Code	Subject Name
01.	ME-AR203A	Flexible Manufacturing System
02.	ME-AR203B	Simulation, Modeling & Control
03.	ME-AR203C	FEM
04.	ME-AR203D	Industry 4.0
05.	ME-AR203E	Sensor, Microprocessor & Microcontroller
06.	ME-AR203F	Data Analytics

Elective (IV) - Semester II

Sr. No.	Subject Code	Subject Name
01.	ME-AR204A	Additive Manufacturing
02.	ME-AR204B	Manufacturing Automation
03.	ME-AR204C	Soft Computing Techniques
04.	ME-AR204D	CAD-CAE
05.	ME-AR204E	Process Control Automation
06.	ME-AR204F	Internet of Things

Open Elective I - Semester II

Sr. No.	Subject Code	Subject Name
01.	ME-AR205A	Research Methodology
02.	ME-AR205B	Numerical Methods & Computational Techniques

Semester-III

Subject Code	Subject	Teaching Scheme				Examination Scheme				
		L	T	P	C	CA	MSE	ESE	OR	Total
ME-AR301	Project Management and Intellectual Property Rights (Self-Study) *	--	--	--	02	50	--	--	50	100
ME-AR302	Project Stage -I	--	--	--	10	50	--	--	50	100
					12	**100**			**100**	**200**

Semester-IV

Subject Code	Subject	Teaching Scheme				Examination Scheme				
		L	T	P	C	CA	MSE	ESE	OR	Total
ME-AR401	Project Stage-II	--	--	--	20	100	--	--	100	200
Total					**20**	**100**			**100**	**200**

Semester-I
Mechatronics

ME-AR101	Mechatronics	L-T-P	3-1-0	4 Credits

Pre-Requisites: Basic Electronics

Mid Semester 20 Marks	Continuous Assessment 20 Marks	End-Semester Exam 60 Marks	Total 100 Marks

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

CO1	Define sensor, transducer and understand the applications of different sensors and transducers
CO2	Explain the signal conditioning and data representation techniques
CO3	Analyze PI, PD and PID controllers for a given application
CO4	Understand applications of microprocessor and micro controller

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	1	1	1	3	2				2	1		1
CO2	3	2			3	3	2				1	3
CO3	3			1	3	2	3					2
CO4	3	3	1	1	3		1	1	1			

Course Contents:

Unit I: Introduction

Introduction to Mechatronic systems, elements, advantages and practical examples of Mechatronic systems.

Unit II: Sensors and Transducers: Various types of sensors and transducers used in Mechatronic system such as pressure sensors, temperature sensors, velocity sensors, Acceleration sensors, proximity sensors, position sensors, force sensors, Optical encoders, Capacitive level sensor, tactile sensors, Selection of sensors.

Unit III: Signal Conditioning and Data Representation

Types of electronic signals, Need for signal processing, Opto-isolators, Protection devices, Analogue to Digital and Digital to Analog Converters, Relays, Contactor, display

Unit IV: Electrical Drives: Types of Electrical Motors, AC and DC motors, servomotors, Stepper motors, linear motors, etc.

Unit V: System Model On/Off controller, Proportional Control, Integral control, Derivative Control; PI, PD and PID Controllers.

Unit VI: Microprocessor and Microcontroller

8085 microprocessor architecture, Instruction sets, various pins and their functions 8081 microcontroller architecture, Instruction sets, various pins and their functions

Texts:

1. HMT Limited, "Mechatronics", Tata McGraw Hill Publications, 1998.

2. W. Bolton, "Mechatronics; Electronic Control System in Mechanical Engineering", Pearson Education Asia, 1999.

3. Raven, "Automatic Control Engineering", Tata McGraw Hill Publications, New York, 1986.

References:

1. R. K. Rajput, "A textbook of Mechatronics", S. Chand and Co., 2007.

2. Michael B. Histand, David G. Alciatore, "Introduction to Mechatronics and Measurement Systems", Tata McGraw Hill International Editions, 2000.

3. D. A. Bradley, D. Dawson, N. C. Buru, A. J. Loader, "Mechatronics", Chapman and Hall, 1993

Semester-I
Industrial Hydraulics & Pneumatic

ME-AR102	Industrial Hydraulics & Pneumatic	L-T-P	3-1-0	4 Credits

Pre-Requisites: None

Mid Semester 20 Marks	Continuous Assessment 20 Marks	End-Semester Exam 60 Marks	Total 100 Marks

Course Outcomes: At the end of the course the student will be able to:

CO1	Define pump, motor and to understand the applications of different pump and motor
CO2	Understand different actuator and control system
CO3	Design pneumatic and hydraulic circuits for a given application
CO4	Understand applications of different direction control valve
CO5	Analyze the use of different sensor and actuator for a given application
CO6	Perform different Trouble Shooting and Remedies in Hydraulic and Pneumatic systems,

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1												
CO2												
CO3												
CO4												
CO5												
CO6												

Course Contents:

Unit I: Fluid Power Principles and Hydraulic Pumps

Types of fluids, Properties of fluids and selection, Pascal's Law, Principles of flow, Friction loss, Work, Power and Torque, Pump Classification , Construction, Working, Design, Advantages, Disadvantages, Selection criteria of Linear and Rotary, Fixed and Variable displacement pumps.

Unit II: Hydraulic Actuators and Control Components

Hydraulic Actuators: Cylinders, Types and construction, Application, Hydraulic cushioning , Hydraulic motors , Control Components : Direction Control, Flow control and pressure control valves, Types, Construction and Operation, Servo and Proportional valves, Applications, Accessories : Reservoirs, Pressure Switches, Applications, Fluid Power ANSI Symbols

Unit III: Hydraulic Circuits and Systems

Accumulators, Intensifiers, Industrial hydraulic circuits, Regenerative, Pump Unloading, Double-

Pump, Pressure Intensifier, Air-over oil, Sequence, Reciprocation, Synchronization, Fail-Safe, Speed Control, Hydrostatic transmission, Electro hydraulic circuits

Unit IV: Pneumatic and Electro Pneumatic Systems

Properties of air , Perfect Gas Laws , Compressor , Filters, Regulator, Lubricator, Muffler, Air control Valves, Quick Exhaust Valves, Pneumatic actuators, Design of Pneumatic circuit , Cascade method, Electro Pneumatic System

Unit V: Industrial Circuits

Simple reciprocating, Regenerative, Speed control (Meter in, Meter out and bleed off), Sequencing, Synchronization, transverse and feed, circuit for riveting machine, automatic reciprocating, fail safe circuit, counter balance circuit, actuator locking, circuit for hydraulic press, unloading circuit

Unit VI: Trouble Shooting and Applications

Installation, Selection, Maintenance, Trouble Shooting and Remedies in Hydraulic and Pneumatic systems, Design of hydraulic circuits for Drilling, Planning, Shaping, Surface grinding, Press and Forklift applications. Design of Pneumatic circuits for Pick and Place applications and tool handling in CNC Machine tools,

Text books:

1. Esposito, Fluid Power with application, Prentice Hall
2. Majumdar S.R, Oil Hydraulic system- Principle and maintenance, Tata McGraw Hill
3. Majumdar S.R, Pneumatics Systems Principles and Maintenance, Tata McGraw Hill
4. H.L.Stewart, Hydraulics and Pneumatics, Taraporewala Publication

Reference books:

1. J. J. Pipenger, Industrial Hydraulics, McGraw Hill
2. Pinches, Industrial Fluid Power, Prentice Hall
3. D. A. Pease, Basic Fluid Power, Prentice Hall
4. B. Lall, Oil Hydraulics, International Literature Association
5. Yeaple, Fluid Power Design Handbook
6. Andrew A. Parr, Hydraulics and Pneumatics, Elsevier Science and Technology Books.
7. ISO - 1219, Fluid Systems and components, Graphic Symbols
8. Michael J, Prinches and Ashby J. G, "Power Hydraulics", Prentice Hall.
9. Dr. R.K. Bansal, Fluid Mechanics, Laxmi Publication (P) Ltd.
10. Product Manuals and books from Vickers/ Eaton, FESTO, SMC pneumatics

Semester-I
Industrial Automation

ME-AR103	Industrial Automation	L-T-P	3-1-0	4 Credits

Pre-Requisites: Nil

Mid Semester 20 Marks	Continuous Assessment 20 Marks	End-Semester Exam 60 Marks	Total 100 Marks

Course Outcomes:

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

CO1	Understand the need of automation
CO2	Classify various types of automated transmission lines and components of automation.
CO3	List and understand various material handling systems.
CO4	Design various types of automated assembly systems
CO5	Explain different control technologies in automation system
CO6	Explain various automatic inspection systems

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2			2	3	1	2	1			
CO2	3				2	2	1		2			
CO3	3				1	1	1		1			
CO4	2	2	3		3	2	2		2			
CO5	2				2	1	2		1			
CO6	2	3	3	3	2	2						

Note: 1- Means least contribution 2- Means medium contribution 3- Maximum contribution

Course Contents:

Unit-I: Introduction

Automation in Production System, Principles and Strategies of Automation, Basic Elements of an Automated System, Advanced Automation Functions, Levels of Automations. Production Economics: Methods of Evaluating Investment Alternatives, Costs in Manufacturing, Break-Even Analysis, Unit cost of production, Cost of Manufacturing Lead time and Work-in process.

Unit-II: Detroit-Type Automation

Automated Flow lines, Methods of Work-part Transport, Transfer Mechanism, Buffer Storage, Control Functions, and Automation for Machining Operations, Design and Fabrication Considerations.

Analysis of Automated Flow Lines: General Terminology and Analysis, Analysis of Transfer Lines Without Storage, Partial Automation, Automated Flow Lines with Storage Buffers,

Unit-III: Material handling and Identification Technologies

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, Work-in-process Storage, Interfacing Handling and Storage with Manufacturing. Product identification system: Barcode, RFID etc.

Unit-IV: Automated Assembly Systems

Design for Automated Assembly, Types of Automated Assembly Systems, Part Feeding Devices, Analysis of Multi-station Assembly Machines, Analysis of a Single Station Assembly Machine.

Unit-V: Control Technologies in Automation

Industrial Control Systems, Process Industries Verses Discrete- Manufacturing Industries, Continuous Verses Discrete Control, Computer Process Control and its Forms. Computer Based Industrial Control: Introduction & Automatic Process Control, Building Blocks of Automation System: LAN, Analog & Digital I/O Modules, and SCADA System & RTU.

Unit-VI: 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, Machine Vision, Other optical Inspection Methods.

Text Books:

1. "Automation, Production Systems and Computer Integrated Manufacturing"- M.P. Grover, Pearson Education.

Reference Books:

1. "Computer Based Industrial Control" – Krishna Kant, EEE-PHI
2. Principles and Applications of PLC – Webb John, Mcmillan 1992
3. "An Introduction to Automated Process Planning Systems" – Tiess Chiu Chang & Richard A. Wysk
4. "Anatomy of Automation" – Amber G.H & P.S. Amber, PrenticeHall.

Semester-I

Concepts of Mechanical Elements

ME-AR104A	Concepts to Mechanical Elements	L-T-P	3-0-0	3 Credits

Pre-Requisites: None

Mid Semester 20 Marks	Continuous Assessment 20 Marks	End-Semester Exam 60 Marks	Total 100 Marks

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

CO1	Define basic terminology of kinematics of mechanisms.
CO2	Apply basic procedure for the selection of machine components
CO3	Describe the various power transmitting elements.
CO4	Suggest methods and devices for measurement of length, angle etc. and techniques to minimize the errors in measurement.
CO5	Identify the manufacturing process for specific application.

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1												
CO2												
CO3												
CO4												
CO5												

Course Content:

Unit I: Simple Mechanisms

Definition of link, pair, kinematics chain, inversions, inversions of single and double slider crank chain, kinematic diagrams of mechanisms, equivalent linkage of mechanism, degree of freedom.

Unit II: Design principles

Concepts of Stress, Strains and theories of failure, Concepts of Fatigue and Creep, Material selection. Strength, rigidity and wear considerations, Design for strength, static and dynamic loadings. Manufacturing consideration, limits, fits and standardization.

Unit III: Mechanical Elements

Shafts, gears, bearings, keys, splines, springs. Riveted, bolted, welded and friction joints. Power screws. Theory and principles of design of couplings, clutches, brakes, belt and chain drives,

spur, helical, bevel and worm gear drives.

Unit IV: Engineering Materials

Engineering materials, Types of material, classification of engineering materials, properties of materials and their testing methods, strengthening and testing of materials,

Unit V: Metrology and mechanical Measurement

Engineering metrology, various instruments for linear and angular measurements, possible errors and remedies, mechanical measurements, methods and devices for measurement of pressure, flow, force, torque, strain, velocity, displacement, acceleration, temperature.

Unit VI: Manufacturing Processes

Manufacturing introduction, Types of manufacturing processes, Types of manufacturing systems, Additive manufacturing, various additive manufacturing methods, subtractive manufacturing, and various subtractive manufacturing methods.

Text Books / References:

1. Shigley, J.E. and Mitchel, L.D., Mechanical Engineering Design, McGraw-Hill International; 1993.
2. Juvinal, R.C., Fundamentals of Machine Component Design, John Wiley and Sons, 1994.
3. Thomas Beven, "Theory of Machines", CBS Publishers and Distributors, Delhi.
4. S. Ramamrutham, "Strength of Materials", DhanpatRai and Sons, New Delhi.
5. W. D.Callister, "Materials Science and Engineering: An Introduction", John Wiley and Sons, 5th edition, 2001.
6. R. K. Jain, "Engineering Metrology", Khanna Publications, 17th edition, 1975.
7. R. K. Jain, "Mechanical & Industrial Measurements", Khanna Publishers.
8. Dieter G.E, "Mechanical Metallurgy (Sl Edition), McGraw Hill Book Co., 1988
9. Serope Kalpakjian and Steven R. Schmid, "Manufacturing Engineering and Technology", Addison Wesley Longman (Singapore) Pte. India Ltd., 6 thedition, 2009.

Semester-I

Concepts of Electronics & Electrical Elements

ME-AR104B	**Concept to Electronics & Electrical Elements**	**L-T-P**	**3-0-0**	**3 Credits**

Pre-Requisites: None

Mid Semester 20 Marks	Continuous Assessment 20 Marks	End-Semester Exam 60 Marks	Total 100 Marks

Course Outcomes: At the end of the course the student will be able to:

CO1	List and explain functioning of basic electronic components
CO2	Explain working of various types of amplifiers
CO3	Analyze various signal conditioning methods
CO4	Understand working of various types of electrical and electronic drives.
CO5	Develop simple circuits using microprocessors and microcontrollers

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1												
CO2												
CO3												
CO4												
CO5												

Course Contents:

Unit I: Basic Electronics
Diode, Transistor Biasing and Introduction to experimental mode of transistor (Low frequency and high frequency analysis),

Unit II: Amplifiers
Operation amplifiers-Application of operational amplifier characteristics and equivalent circuits, Power amplifier: Class A, Class B, Class C, Class AB efficiency calculation and heat sinks. Feedback amplifiers-Advantages, disadvantages, Classification (positive and negative feedback), V & I feedback.

Unit III: Signal Conditioning
Oscillators-PC phase shift, LC Wein Bridge & crystal, Digital- Number system, Boolean algebra, Gates, K-map, sequential circuits, Brief introduction of-Transformer.

Unit IV: Electrical and Electronic Drives
Motors (AC and DC), Solid state devices- SCR, IGBT, Converters & Invertors, Variable speed drives (AC & DC)

Unit V: Sensors and Transducers
Various types of sensors and Transducers, applications of sensors for automation.

Unit VI: Microprocessors and microcontrollers
Introduction to microprocessors and microcontrollers, commonly used microprocessors and microcontrollers, developing simple circuits using commonly used microprocessors and microcontrollers, popular open ware hardware.

Text Books / References:

1. Integrated Electronics MillmanHalkias Tata McGraw-Hill
2. Digital Design M. Morris Mano McGraw-Hill
3. Operational Amplifier-Linear Integrated Circuits Gayakwad Prentice Hall India
4. Power Electronics Mohammad H. Rasid Prentice Hall India Electrical and Electronics Measurement &
5. Instrumentation A.K. Sawhney DhanpatRai& Sons

Semester-I
Metrology and Computer Aided Inspection

ME-AR105A	Metrology and Computer Aided Inspection	L-T-P	3-0-0	3 Credits

Pre-Requisites: None

Mid Semester 20 Marks	Continuous Assessment 20 Marks	End-Semester Exam 60 Marks	Total 100 Marks

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

CO1	Explain high precision measurement requirements of industry and select instruments for high precision.
CO2	Using various measuring standards and instruments for different applications.
CO3	Calibrate basic metrology instruments used in machine shop, and Identify techniques to minimize the errors in measurement.
CO4	Employing limits and design gauges
CO5	Explain the different instruments used for linear and angular measurements, surface finish and form features of a component

CO6	Identify the advanced measurement principles with ease and operate sophisticatedmeasurement machines.

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	1	1			2	2						1
CO2	2	1	3	1	1	1						
CO3	2	2		3								2
CO4	2	2	2		3							2
CO5		1	1		1							1
CO6						3						2

Course Contents:

Unit I

Metrological concepts, Abbe's principle, need for high precision measurements, problems associated with high precision measurements.

Unit II

Standards for length measurement, shop floor standards and their calibration, light interference, method of coincidence.

Unit III

Slip gauge calibration, measurement errors, various tolerances, and their specifications, gauging principles.

Unit IV

Selective assembly, comparators, angular measurements, principles and instruments, gear and thread measurements.

Unit V

Surface and form metrology, computer aided metrology, principles and interfacing, software metrology, laser metrology, CMM, types, probes used applications.

Unit VI

Non-contact CMM using electro-optical sensors for dimensional metrology, non-contact sensors for surface finish measurements, image processing and its applications in metrology.

TEXTS / REFERENCES:

1. D.J.Whitehouse, *Handbook of Surface Metrology*, Inst. of Physics Bristol and Philadelphia, 1994.
2. R.K.Jain, *Engineering Metrology*, Khanna Publishers, 2000.
3. Galleyer and Shotbolt, *Metrology for Engineers*, ELBS, 1998

Semester-I

Product Design and Development

ME-AR105B	Product Design and Development	L-T-P	3-0-0	3 Credits

Pre-Requisites: None

Mid Semester 20 Marks	Continuous Assessment 20 Marks	End-Semester Exam 60 Marks	Total 100 Marks

Course Outcomes: At the end of the course the student will be able to:

CO1	Create new product based on mechanical design engineering.
CO2	Understand all mechanical aspects of product design by incorporating concept, creativity, structural, manufacturing, aesthetic etc.
CO3	Solve open-ended problem belongs to design engineering that meet the requirements.
CO4	Understand contemporary issues and their impact on provided solution.

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1												
CO2												
CO3												
CO4												

Course contents:

Unit: I Design Fundamentals

The importance of engineering design – types of design –the design process – relevance of product lifecycle issues in design –designing to codes and standards- societal considerations in engineering design –generic product development process – various phases of product development-planning for products –establishing markets- market segments- relevance of market research.

Unit II: Customer oriented design & Societal Considerations

Identification of customer needs- customer requirements- Quality Function Deployment Product Design Specifications- Human Factors in Design – Ergonomics and Aesthetics. Stress, Strain in 2-d and 3-d,

relation between stress and strain, theories of failure.

Unit III: Material selection processing and Design

Material Selection Process – Economics – Cost Vs Performance – Weighted property Index – Value Analysis – Role of Processing in Design – Classification of Manufacturing Process – Design for Manufacture – Design for Assembly –Designing for castings, Forging, Metal Forming, Machining and Welding – Residual Stresses – Fatigue, Fracture and Failure. 08 Hrs.

Unit IV: Design Methods

creativity and problem solving- creative thinking methods- generating design concepts - systematic methods for designing –functional decomposition – physical decomposition – functional representation – morphological methods-TRIZ- axiomatic design. Decision making theory- utility theory –decision trees – concept evaluation methods. - 10 Hrs.

Unit V: Industrial Design concepts

human factors design –user friendly design – design for serviceability – design for environment – prototyping and testing – cost evaluation –categories of cost –overhead costs – activity based costing – methods of developing cost estimates – manufacturing cost –value analysis in costing. Dimensioning and tolerancing a product-functional production and inspection datum-tolerance analysis.

Texts/References

1. Product Design, by Kevin Otto, Kristin wood, Pearson Education Inc.
2. Product design and development, by K.T. Ulrich and S.D. Eppinger, Tata McGraw Hill
3. Product Development, by Chitale & Gupta, Tata McGraw Hill
4. The Mechanical Process Design, by David Ullman, McGrawhill Inc
5. Product design & process Engineering by Niebel & deeper, McGraw hill
6. Value Management by Heller, Addison Wasley
7. Value engineering a how to Manual S.S.Iyer, New age International Publishers
8. New Product Development Timjones. Butterworth Heinmann, Oxford.
9. Assembly automation and product design – by Geoffrey Boothroyd, CRC Taylor & Francis

Semester-I

Design of Mechanisms and Manipulators

ME-AR105C	Design of Mechanisms and Manipulators	L-T-P	3-0-0	3 Credits

Pre-Requisites: None

Mid Semester 20 Marks	Continuous Assessment 20 Marks	End-Semester Exam 60 Marks	Total 100 Marks

Course Outcomes: At the end of the course the student will be able to:

CO1	Understand the basic concepts of kinematics.
CO2	Aware Link coordinate diagram and arm matrix
CO3	Recognize Structural Analysis and Synthesis of mechanisms
CO4	Understand the basic concepts of Manipulators.

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1												
CO2												
CO3												
CO4												

Course Contents:

Unit I: Kinematics
Mobility analysis, Degree of Freedom (DOF), Mixed Mobility, Total, Partial and Fractional DOF, Closed and Open Chain Systems, Application of D-H representation for 1) Kinematic parameter tables for standard robot structures.

Unit II: Link coordinate diagram and arm matrix
Link coordinate diagram and arm matrix of SCARA, Alpha II, PUMA articulated robot, standard robot, polar frame, structure robot, Enter transform solution, Arm matrix of standard Robots, Polar frame, structure robots

Unit III: Structural Analysis and Synthesis of mechanisms
Structural Analysis and Synthesis of mechanisms, Alternative design solutions; Coding, evaluation and selection of optimum mechanism. Type synthesis, number synthesis and design of mechanisms. Indexes of merit; Graphical, Algebraic and Optimization techniques, Matrix methods of design and analysis; Design of function, Path and Motion Generators; Structural and Mechanical error; Design and Analysis using software.

Unit IV: Manipulators
Classifications, actuation and transmission systems; Coordinate Transformation – DH notations, Inverse and Forward kinematics, Manipulator dynamics from Lagrangian and Newtonian point of view.

Unit V: Dynamic Analysis of manipulator
Forces in Manipulator, manipulate Dynamics, selecting of robots for Robot Application Reliability of Robotic & Automation systems and their evaluation.

Unit VI: Gripper Design
Linkage activated grippers: kinematic and dynamic design, other principles of gripping like, magnetic grippers, adhesive grippers, internally expanding grippers, mandrels, etc. their static and dynamic analysis.

Text Books / References:
1. Andeen, G.B., "Robort Design Hand Book", SRI International, McGraw Hill,
2. Craig, J.J., "Introduction to Robotics", Mechanics and Control, Addison Wesley
3. Spong, M., and Vidyasagar, M. "Robot Dynamics and Control", John Wiley, NY, 1989.
4. Venkataraman. S.T., and liberall. T., "Dextrous Robot Hands", S
5. AppuKuttan, "Robotics", I.K. International Publishing house

Semester-I

Artificial Intelligence & Expert System in Automation

ME-AR105D	**Artificial Intelligence & Expert System in Automation**	**L-T-P**	**3-0-0**	**3 Credits**

Pre-Requisites: None

Mid Semester 20 Marks	Continuous Assessment 20 Marks	End-Semester Exam 60 Marks	Total 100 Marks

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

CO1	Know the expert system architecture
CO2	Select appropriate AI technique for a given problem
CO3	Develop neural network or fuzzy logic or genetic algorithm for a given situation
CO4	Understand the basics of machine learning
CO5	Apply the principles of machine learning and AI for practical applications.

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1												
CO2												
CO3												
CO4												
CO5												

Course Contents:

Unit I: Expert system Architecture
Expert system Architecture, knowledge base, inference engine, expert system shell, applications.

Unit II: Fuzzy Logic
Fuzzy sets, membership functions, operation on fuzzy sets; fuzzy control system, Fuzzyfication, knowledge base, inference, defuzzification, application.

Unit III: Neural Network
Neuron structure, classification, artificial neural network, back propagation training and algorithm, neuro-fuzzy controllers, applications.

Unit IV Genetic algorithms
Concepts, encoding and selection methods, genetic operators (crossover and Mutation), applications.

Unit V Hybrid systems
Neuro-fuzzy hybrid systems – genetic neuro hybrid systems – genetic fuzzy hybrid and fuzzy genetic hybrid systems – simplified fuzzy ARTMAP – Applications: A fusion approach of multispectral images with SAR, optimization of traveling salesman problem using genetic algorithm approach, soft computing based hybrid fuzzy controllers.

Unit VI: Artificial intelligence and machine learning:
Definition, knowledge representation techniques, problem solving, search techniques, game playing , knowledge and logic, learning methods, applications of AI.

Text Books / References:
1. Haykin "Neural Networks – A comprehensive Foundation" (Mc-millan)
2. J.M. Zureda "Introduction to artificial neural networks" (Jaico)
3. A Cichocki& R Unbehauen " Neural Networks for optimization and signal Processing" John Wiley
4. George J. Klin& Tina A Polgar "Fuzzy sets, uncertainty and Information"
5. BaertKosko "Neural network and fuzzy systems"
6. Peterson "Introduction to Artificial Intelligence and expert system (PHI)
7. Michell "Introduction to Genetic Algorithm" (PHI)

8. Vidyasagar M "Theory of learning and generalization" Springer
9. S. Rajasekaran, G.A. Vijaylakshmi Pai "Neural Networks, Fuzzy Logic and Genetic Algotithm", PHI.
10. T.J. Ross: "Fuzzy Logic with Engineering Applications" Second Edition John Wiley India.

Semester-I
Communication Skills

BSH16	Communication Skills	L-T-P	2-0-0	2 Credits

Pre-Requisites: None

Continuous Assessment 25 Marks	PR/OR 25 Marks	Total 50 Marks

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

CO1	Students are found to be confident while using English
CO2	Engage in analysis of speeches or discourses and several articles
CO3	Identify and control anxiety while delivering speech
CO4	Write appropriate communications(Academic/Business)
CO5	Prepared to take the examinations like GRE/TOFEL/IELTS
CO6	Identify and control the tone while speaking
CO7	Develop the ability to plan and deliver the well-argued presentations

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2		1		2		2	1			2	3
CO2	2						1	2		1	2	3
CO3					1		1	2			2	3
CO4	2		1		1		3	1	2	1	2	3
CO5	1											1
CO6					2		2	2			2	3
CO7			2	1	2	2	3	3	1	1	3	3

Course Contents:

Unit I: Communication and Communication Processes

Introduction to Communication, Forms and functions of Communication, Barriers to Communication and overcoming them, Verbal and Non-verbal Communication, Ways of

Effective Communication.

Unit II: Oral Communication

Use of Language in Spoken Communication, Features of Good Communication, Principles and Practice of Group Discussion, Public Speaking (Addressing Small Groups and Making Presentation), Interview Techniques, Appropriate Use of Non-verbal Communication, Presentation Skills, Telephonic Etiquettes, Extempore, Elocution, Describing Experiences and Events.

Unit III: Study of Sounds in English

Introduction to phonetics, Study of Speech Organs, Study of Phonemic Script, Articulation of Different Sounds in English, Stress Mark.

Unit IV: English Grammar

Grammar: Forms of Tenses, Articles, Prepositions, Use of Auxiliaries and Modal Auxiliaries, Synonyms and Antonyms, Common Errors, Sentence Formation and Sentence Structures, Use of Appropriate Diction.

Unit V: Writing Skills

Features of Good Language, Difference between Technical Style and Literary Style, Writing Emails, Formal and Informal English, Business Writing, Advertisements, Essay Writing, (Technical, Social, and Cultural Topics), Technical Reports: Report Writing: Format, Structure and Types, Writing Memorandum, Circulars, Notices, Agenda and Minutes, Technical Manuals, Brochures

Letter Writing: Types, Parts, Layouts, Letters and Applications, Use of Different Expressions and Style, Writing Job Application Letter and Resume.

Unit VI: Reading Skills & Listening Skills

Reading: Introduction to Reading, Barriers to Reading, Types of Reading: Skimming, Scanning, Fast Reading, Strategies for Reading, Comprehension.

Listening : Importance of Listening, Types of Listening, Barriers to Listening.

TEXTS/ REFERENCE:

1. Mohd. Ashraf Rizvi, *Communications Skills for Engineers*, Tata McGraw Hill
2. Sanjay Kumar, Pushp Lata, *Communication Skills*, Oxford University Press, 2016
3. Meenakshi Raman, Sangeeta Sharma, *Communication Skills*, Oxford University Press, 2017
4. Teri Kwal Gamble, Michael Gamble, *Communication Works*, Tata McGraw Hill Education, 2010

Semester-I

Automation and Robotics Laboratory

ME-AR107	Automation and Robotics Laboratory	L-T-P	0-0-3	2 Credits

Pre-Requisites: None

Continuous Assessment 25 Marks	PR/OR 25Marks	Total 50 Marks

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

CO1	
CO2	
CO3	
CO4	
CO5	
CO6	

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1												
CO2												
CO3												
CO4												
CO5												
CO6												

Course Contents:

At least six of the following experiments should be conducted on the appropriate hardware

1. Study and demonstration of various types of sensors.
2. Minimum two circuits on Pneumatics and Electro-Pneumatics to be developed on Pneumatic trainer kit
3. Minimum two circuits on Hydraulics and Electro-hydraulics to be developed on Hydraulic trainer kit
4. Design Hydraulic /Pneumatic circuit for different automation projects.
5. Speed control of various types of Electrical Motors.
6. Write PLC program for automation project using ladder logic.
7. Design pneumatic cascade circuit for automation projects.
8. Write program for base shifting
9. Create new program for different types of motion (PTP, Linear, Circular etc)

Semester-II

Industrial Robotics

ME-AR201	Industrial Robotics	L-T-P	3-1-0	4Credits

Pre-Requisites: Engineering mathematics-I

Mid Semester 20 Marks	Continuous Assessment 20 Marks	End-Semester Exam 60 Marks	Total 100 Marks

Course Outcomes: At the end of the course the student will be able to:

CO1	Classify various types of robotic configurations
CO2	Recommend appropriate robot configurations for various applications.
CO3	Solve problem based on Kinematics and dynamics
CO4	Select appropriate type of drive, gripper and sensor for Robot
CO5	Write program for specific application.
CO6	Understand various implementation issues for robotics

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3					1	1					
CO2	2	2			3	2						
CO3		2			2	1		3				
CO4	2	3				3		3				
CO5	2				3		1					
CO6				3		2						

Course Contents:

Unit-I: Introduction

Introduction: Basic Concepts, laws of Robotics, Robot anatomy, links, joint and joint notation scheme, arm wrist and end effector configuration, work volume, Classification, structure of robots, point to point and continuous path robotic systems. Robot performance- resolution, accuracy, repeatability, dexterity, compliance, Applications.

Unit-II: Robot Kinematics and Dynamics

Kinematics: Forward and reverse kinematics (Transformation) of three DOF robot arm, Transformation of four DOF manipulator. Homogeneous transformation. Kinematic equation using homogeneous transformation. Transformation matrices and their arithmetic, link and joint description, Denavit–Hartenberg parameters, frame assignment to links, robot arm dynamics.

Unit-III: Robotic sensor and drive

Sensors in Robotics: sensory devices, types of sensors such as Position sensor, velocity sensor, proximity sensors, touch sensors, force sensors, robot vision system. Function of drive system, types and selection of drives, drive mechanism, Actuators and transmission systems, Types of Controllers, closed loop control, Stepper motor, DC motors, AC motors.

Unit-IV: Robot End-Effector

Types of Grippers, Design of gripper, active and passive gripper, Force analysis for various basic gripper systems including Mechanical, vacuum gripper, magnetic, adhesive, hooks, scoops and other miscellaneous devices,

Unit-V: Robot Programming

Methods of robot programming, lead through programming subroutines, Programming Languages: Robot language structure, Introduction to various types such as RAIL and VAL, ROS. Coordinator system, Teach pendant functions, Types of modes, New program creation using different types of motion like PTP, Linear, Circular etc. Tool calibration, Base calibration, Base Shifting, axis limit, Safety interlock, digital input/output configuration, program in loop,

Unit-VI:

Applications of Robots & Implementation Issues

Application of robots in Material Handling, process operations and Assembly and inspection. Approach for implementing Robotics, Safety, Training and Maintenance Social Aspects of Robotics.

Text Books:

1. S. R. Deb, Robotics Technology and Flexible Automation, Tata McGraw Hill.

REFERENCES:

1. Groover M.P.-Automation, production systems and computer integrated manufacturing‘- Prentice Hall of India
2. S B Niku, Introduction to Robotics, Analysis, Control, Applications, 2nd Edition, Wiley Publication, 2015.
3. John Craig, Introduction to Robotics, Mechanics and Control, 3rd Edition, Pearson Education, 2009
4. Mathia, Robotics for Electronics Manufacturing, Cambridge Uni. Press, India
5. A Ghosal, Robotics: Fundamental Concepts and Analysis, Oxford University Press, 2013. 6. R K Mittal & I J Nagrath, Robotics and Control, McGraw Hill Publication, 2015.

Semester-II

Drives and Control System for Automation

ME-AR202	Drives and Control System for Automation	L-T-P	3-1-0	4 Credits

Pre-Requisites: None

Mid Semester 20 Marks	Continuous Assessment 20 Marks	End-Semester Exam 60 Marks	Total 100 Marks

Course Outcomes: At the end of the course the student will be able to:

CO1	To understand working principles of various types of motors, differences, characteristic and selection criteria.
CO2	To apply the knowledge in selection of motors, heating effects and braking concepts various industrial applications
CO3	To elucidate various linear and rotary motion principles and methods and use the same to application areas
CO4	To carry out programming using PLC and use of various PLCs to Automation problems Industries.
CO5	To discuss supervisory control and data acquisition method and use the same in comple automation areas
CO6	To understand and use logical elements and use of Human Machine Interfacing devices to enhance control & communication aspects of Automation

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1												
CO2												
CO3												
CO4												
CO5												
CO6												

Course Contents:

Unit I: Introduction

Working principle of synchronous, Asynchronous & stepper motors, Torque v/s speed characteristics, Power v/s. motor rating, heating effects, electric braking, Speed characteristics, variable frequency drive, servo drive

Unit II: Motion laws for rotary and linear systems

Converting rotary to linear system, concepts and principles of ball screws, rack and pinion, belt and pulley, chain drives, gear drives

Unit III: Introduction to Programmable Logic Controllers
Definitions of PLC, basic structure of PLC, difference between relay logic and PLC, software, programming software tool and interfacing with PC (RS232 & TCP-IP), methods of PLC programming, types of tasks and configuration,

Unit IV: Logic, instructions and its Application
Logic gates: OR, AND, NOT logic, Ex Or logic, Analysis of rung. Timer and Counter Instructions; on delay and Off delay and retentive timer instructions, PLC counter up and down instructions, combining counters and timers, Comparison and data handling instructions, Sequencer instruction.

Unit V: Visualization Systems
Visualization Systems, Types of visualization system, PC based Controller, Applications of HMI's, and Interfacing of HMI with controllers.

Unit VI: Supervisory control & data Acquisitions
Introduction to Supervisory control & data Acquisitions, distributed Control System (DCS): computer networks and communication in DCS. different BUS configurations used for industrial automation – GPIB, HART and OLE protocol, Industrial field bus – FIP (Factory Instrumentation Protocol), PROFIBUS (Process field bus), Bit bus. Interfacing of SCADA with controllers, Basic programming of SCADA, SCADA in PC based Controller / HMI,

Text Books:
1. Process Control Instrumentation Technology, Johnson Curties, Prentice hall of India, 8th edition
2. Andrew Parr, Industrial drives, Butterworth – Heineamann
3. G.K.Dubey.Fundamentals of electrical drives
4. Programmable Logic Controllers by W.Bolton

References:
1. Introduction to Programmable Logic Controllers by Garry Dunning, 2nd edition, Thomson, ISBN:981-240-625-5
2. Instrumentation Engineers Hand Book - Process Control, Bela G Liptak, Chilton book company, Pennsylvania
3. A.E. Fitzerald ,C.Kingsley and S.D Umans, Electric Machinery - McGraw Hill Int. Student edition
4. S.K.Pillai. A First course on electric drives –Wiley Eastern 1990

Semester-II

Flexible Manufacturing Systems

ME-AR203A	Flexible Manufacturing Systems	L-T-P	3-0-0	3 Credits

Pre-Requisites: None

Mid Semester 20 Marks	Continuous Assessment 20 Marks	End-Semester Exam 60 Marks	Total 100 Marks

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

CO1	
CO2	
CO3	
CO4	
CO5	

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1												
CO2												
CO3												
CO4												
CO5												

Detailed Syllabus:

Unit I: Introduction

FMS definition and classification of manufacturing systems, automated production cycle, Need of flexibility, Concept of flexibility, Types of flexibilities and its measurement.

Unit II: Economic Analysis

Why FMS, Factors responsible for the growth of FMS, FMS types and applications, Economic justification for FMS.

Unit III: FMS Equipment

Functional requirements for FMS equipments, FMS processing and QA equipment, e.g., turning and machining centers, Co-ordinate measuring machines, Cleaning and deburring machines, FMS system support equipment, Automated material handling and storage equipment, cutting tool and tool management, Work holding considerations, Fixture considerations in FMS environment.

Unit IV: Group Technology

GT concepts, Advantages of GT, Part family formation-coding and classification systems; Part-

machine group analysis, Methods for cell formation, Use of different algorithms, mathematical programming and graph theoretic model approach for part grouping, Cellular Vs FMS production.

Unit V: Plant layout, FMS and GT layouts
FMS design problems: Part assignment, Machine selection, Storage system selection, Selection of pallets and fixtures, Selection of computer hardware and software, designing for layout integration of machine storage, Material handling System and computer system,

Unit VI: Communication networks
FMS planning problems: Strategic planning, Part type selection, Machine grouping, production ratio and resource allocation, Machine loading problems. Operational & Control problems: Part scheduling, Machines robots & AGVS, Process monitoring & control. FMS Implementation: Objectives, acceptance testing, Performance goals and expectation maintenance concerns.

Books:
1. Automation, Production System & Computer Integrated Manufacturing Groover Englewood
2. Design and Operation of SMS Rankey IFS
3. Flexible Manufacturing System Wernecks Spring-Verlag
4. FMS in Practice Bonctto Northox Ford
5. Flexible Manufacturing Cells and systems W.W. Luggen Prentice Hall India
6. Performance Modelling of Automated Manufacturing Vishwanathan&Narahar
Prentice Hall India

Semester-II

Simulation, Modeling & Control

ME-AR203B	**Simulation, Modeling & Control**	**L-T-P**	**3-0-0**	**3 Credits**

Pre-Requisites: None

Mid Semester 20 Marks	Continuous Assessment 20 Marks	End-Semester Exam 60 Marks	Total 100 Marks

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

CO1	Define simulation, its limitations and applications.
CO2	Apply simulation to queuing and inventory situations.
CO3	Acquire knowledge to generate the random numbers for simulation models.
CO4	Analyze the data and verify model of simulation.
CO5	Learn software's and programming languages for developing simulation model.
CO6	Discuss case studies in manufacturing simulation.

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2											1
CO2	2			1								
CO3	2	2	1	2								1
CO4	2	2	1	2						2	1	
CO5	2	2	2	3						1		2
CO6	2						2			1		

Course Contents:

Unit I

Introduction to systems and modeling – discrete and continuous system - Limitations of simulation, areas of application - Monte Carlo Simulation.

Unit II

Discrete event simulation and their applications in queueing and inventory problems.

Unit III

Random number generation and their techniques - tests for random numbers. Random variable generation.

Unit IV

Analysis of simulation data. - Input modeling – verification and validation of simulation models – output analysis for a single model.

Unit V

Simulation languages and packages - FORTRAN, C, C++, GPSS, SIMAN V, MODSIM III, ARENA, QUEST, VMAP - Introduction to GPSS – Case studies.

Unit VI

Simulation of manufacturing and material handling system, Caste studies.

TEXTS / REFERENCES:

1. Jerry Banks and John S, Carson II "Discrete Event System Simulation", Prentice Hall, 1984.
2. Geoffrey Gordon., "System Simulation", Prentice Hall, 1978.
3. Francis Neelamkovil, "Computer Simulation and Modelling", John Willey and sons, 1987.

Semester-II

Finite Element Methods

ME-AR203C	Finite Element Methods	L-T-P	3-0-0	3 Credits

Pre-Requisites: None

Mid Semester 20 Marks	Continuous Assessment 20 Marks	End-Semester Exam 60 Marks	Total 100 Marks

Course Outcomes: At the end of the course the student will be able to:

CO1	Understand the basics principle of FE method
CO2	Identify mathematical model for solution of common problems
CO3	Solve structural, thermal problem using FE in 1D Case
CO4	Derive element stiffness matrix by different methods
CO5	Understand the formulation for 2D and 3D case
CO6	Recognize need for and engage in lifelong learning

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	1	1										
CO2	3	3	1		1							1
CO3	2	2	1	2	2				2			1
CO4	3								2			
CO5	3	2										
CO6			1									3

Course Contents:

Unit I

1-D Problems: Introduction to structural analysis and FEM, Introduction to approximate solutions and FEM, summary of linear elastic mechanics.

Unit II

1-D Problems: Principles of linear elastic mechanics, principles of virtual displacements and minimum potential energy, Rayleigh Ritz method, exact v/s approximate solution, beam elements.

Unit III

2-D Problems: Plane stress and plane strain conditions, triangular elements, constant strain triangle, linear strain triangle, Boundary conditions, body forces and stress recovery, quadrilateral elements.

Unit IV

2-D Problems: Lagrange and Serendipity shape functions, isoparametric formulation, numerical integration, modeling with isoparametric elements, requirements for convergence, patch test, nonconforming elements, reduced integration.

Unit V

3-D Problems: Axisymmetric solids, governing equations, axisymmetric elements and their applications, mixed formulations, bending of flat plates (Kirchhoff Theory), continuity requirements and boundary conditions.

Unit VI

3-D Problems: Discrete Kirchhoff's elements, thick plate elements, plate bending applications, shells as assemblage of flat plates, finite element formulation for dynamic problems, mass properties, introduction to elastic stability for frames and plates.

TEXTS / REFERENCES:

1. R. D. Cook, Concepts and Applications of Finite Element Analysis; John Wiley and Sons, second edition, 1981.
2. C.S. Krishnamurti, Finite element method; Tata Mc-Graw Hill Publication.
3. K.J. Bathe, Finite Element Method and Procedures; Prentice hall, 1996.
4. Tirupathi, R., and Chandrupatla, Finite Elements in Engineering; PHI Publication, New Delhi.
5. Bruce Irons and Soharab Ahmed, Techniques of Finite Elements; John Wiley and Sons, New York.
6. K.J. Bathe, Finite Element Method; Prentice Hall, 1987.
7. O.P., Goptha, Finite and Boundary Element Methods in Engineering; Oxford and IBH.

Semester-II

Industry 4.0

ME-AR203D	**Industry 4.0**	**L-T-P**	**3-0-0**	**3 Credits**

Pre-Requisites: None

Mid Semester 20 Marks	Continuous Assessment 20 Marks	End-Semester Exam 60 Marks	Total 100 Marks

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

CO1	

CO2	
CO3	
CO4	
CO5	

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1												
CO2												
CO3												
CO4												
CO5												

Course Contents:

Unit I: Introduction: Sensing & actuation, Communication, Networking, Industry 4.0: Globalization and Emerging Issues, The Fourth Revolution, LEAN Production Systems, Smart and Connected Business Perspective, Smart Factories

Unit II: Industry 4.0: Cyber Physical Systems and Next Generation Sensors, Collaborative Platform and Product Lifecycle Management, Augmented Reality and Virtual Reality, Artifical Intelligence, Big Data and Advanced Analysis

Unit III: Cyber security in Industry 4.0, Basics of Industrial IoT: Industrial Processes, Industrial Sensing & Actuation, Industrial Internet Systems. IIoT-Introduction, Industrial IoT: Business Model and Reference Architecture: IIoT-Business Models

Unit IV: Industrial IoT: Big Data Analytics and Software Defined Networks: IIoT Analytics - Introduction, Machine Learning and Data Science, R and Julia Programming, Data Management with Hadoop.

Unit V: Application Domains: Oil, chemical and pharmaceutical industry, Applications of UAVs in Industries, Real case studies: Milk Processing and Packaging Industries, Manufacturing Industries etc.

Reference Book

1. "Industry 4.0: The Industrial Internet of Things", by Alasdair Gilchrist (Apress)
2. "Industrial Internet of Things: Cybermanufacturing Systems"by Sabina Jeschke, Christian Brecher, Houbing Song, Danda B. Rawat
3. A. McEwen and H. Cassimally, Designing the Internet of Things, 1st edition, Wiley, 2013, ISBN-10: 111843062X.
4. N. Vengurlekar and P. Bagal, Database Cloud Storage: The Essential Guide to Oracle Automatic Storage Management, 1st edition, McGraw-Hill Education, 2013, ISBN-10: 0071790152.
5. M. Kuniavsky, Smart Things: Ubiquitous Computing User Experience Design, 1st edition, Morgan Kaufmann, 2010, ISBN-10: 0123748992.

Semester-II

Sensors, microprocessors, microcontrollers

ME-AR203E	Sensors, microprocessors, microcontrollers	L-T-P	3-0-0	3 Credits

Pre-Requisites: None

Mid Semester 20 Marks	Continuous Assessment 20 Marks	End-Semester Exam 60 Marks	Total 100 Marks

Course Outcomes: At the end of the Course the student will be able to:

CO1	Understand the general principles of sensors and transducers
CO2	List and explain the principle and working of various types of sensors
CO3	Understand the requirements for networking of sensors
CO4	Understand the architecture of popular microprocessors and microcontrollers.
CO5	Develop simple circuits using popular microprocessors and microcontrollers

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1												
CO2												
CO3												
CO4												
CO5												

Course Contents:

Unit I: Fundamentals of Sensors and Transducers Performance
terminology, static and dynamic characteristics of transducers, classification of sensors and transducers, signal processing and signal conditioning. Operational amplifiers, filters, protection devices, analog to digital converter, digital to analog converter.
Sensors and their applications
Inductive, capacitive, magnetic, various types of photo sensors, detection methods, through-beam detection, reflex detection & proximity detection, ultrasonic and microwave sensors. Applications and understanding of the above sensors.

Unit II: Advanced Sensor Technologies
Laser production, characteristics of lasers, types of laser sensors, bar code sensors, benefits of bar coding, transponder, RFID (Radio Frequency Identification), electromagnetic identifier, optical encoders ,.color sensors, sensing principles, color theory, unit color

measurement, colour comparator, color sensing algorithm, fuzzy logic color sensor. fuzzy logic for optelectronic colour sensor in manufacturing.

Sensors in Flexible Manufacturing Systems: Vision sensors, image transformations, robotvisual sensing tasks, detecting partially visible objects, sensors in flexible manufacturing

Unit III: Networking

Networking of sensors, control of manufacturing process, tracking- the meantime between operations interventions, tracking the yield and mean process time, detection of machining faults, diagnostic systems, resonance vibration analyzer, sensing motor current for signature analysis, temperature sensing.

Unit IV: Sensors for Special Applications

A multi objective approach for selection of sensors inmanufacturing, cryogenic manufacturing applications, semiconductor absorption sensors, semiconductor temperature detector using photoluminescence temperature detectors using point contact, sensors in process manufacturing plants, measurement of high temperature, robot control through sensors, other sensors, collection and generation of process signals in decentralized manufacturing system.

Unit V: Microprocessors

Evolution of Microprocessors, General architecture of **µ**P, an overview of 8086/88/architecture minimum/maximum mode configuration. Assembly Language programming in 8086, interrupt structure Programmed I/O, parallel I/O (8255-PPI) serial I/O (8251/8250), RS-232, IEEE bus standard, 8157 DMA controller A/D & D/A conversion, 8253/54 PIT/counters, 8087 Numerical processor and its interfacing with 8086.

Unit VI: Microcontrollers

Introduction to 8051 micro-controller family: Pin description of 8051 and its internal structure, connections of I/O ports and Memory organization Addressing mode. Instruction set & its format and simple programs. Atmel micro-controller 89C51 and 89C2051.
Introduction to 8096/8097 family and essential difference with 8051.
Applications of microprocessors and micro-controller

Text Books:

1. Sabnesoloman, sensors & control systems in manufacturing. Mc-Graw Hill book Company Network, 1994.
2. Mechatronics by W,Bolton
3. D V Hall, Microprocessor and It's Applications, TMH.
4. B.B. Bray, The Intel Microprocessors 8086/8088, 80186/80188, 80286, 80386, 80486, Pentium and Pentium pro processor, architecture, programming and interfacing, PHI India.
5. Mohammed Refiguzzaman, Microprocessor & Microcomputer Based System Design, Universal Books Stall, New Delhi.
6. Ajay V. Deshmukh "Micro-controllers Theory and Applications." Tata – McGraw Hill companies – 2005.

References:

1. Sensor Technology Handbook by Jon S. Wilson
2. N.L.Buck&T.G.Buckwith, Mechanical measurement.
3. Sensors and Transducers by Ian Sinclair

Semester - II
Data Analytics

ME-AR203F	Data Analytics	L-T-P	3-0-0	3 Credits

Mid Semester 20 Marks	Continuous Assessment 20 Marks	End-Semester Exam 60 Marks	Total 100 Marks

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

CO1	Analyze several key technologies used in manipulating, storing, and analyzing big data
CO2	Acquire clear understanding of processing data
CO3	Acquire clear understanding of Hadoopmap reduce
CO4	Categorize and Summarize Big Data and its importance
CO5	Manage Big Data and analyze Big Data
CO6	Apply tools and techniques to analyze Big Data.

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1												
CO2												
CO3												
CO4												
CO5												
CO6												

Course Contents:

Unit I: Introduction to big data

Big Data and its Importance – Four V's of Big Data – Drivers for Big Data –Introduction to Big Data Analytics – Big Data Analytics applications. Hadoop's Parallel World – Data discovery – Open source technology for Big Data Analytics – cloud and Big Data –Predictive Analytics – Mobile Business Intelligence and Big Data – Crowd Sourcing Analytics – Interand Trans-Firewall, Analytics - Information Management. (SLE: Predictive Analytics)

Unit II: Processing big data

Integrating disparate data stores - Mapping data to the programming framework Connecting and extracting data from storage - Transforming data for processing - Subdividing data in preparation for Hadoop Map Reduce. (SLE: Data Preparation for Map Reduce)

Unit III: Hadoopmapreduce

Employing Hadoop Map Reduce - Creating the components of Hadoop Map Reduce jobs - Distributing data processing across server farms -Executing Hadoop Map Reduce jobs - Monitoring the progress of job flows - The Building Blocks of Hadoop Map Reduce - Distinguishing Hadoop daemons - Investigating the Hadoop Distributed File System Selecting appropriate execution modes: local, pseudo-distributed, fully distributed. (SLE: Applications of HadoopMapreduce)

Unit IV: Database Management System
Comparison of File System, Database Management System, Characteristic Features of Database Management Systems, Relational Databases. (SLE: Logical Database Design) Unit V: Data Base Models DBMS Languages and Interfaces. Data Base Security and Authorization. (SLE: Data Ware House)

Unit VI: Big data tools and techniques
Installing and Running Pig – Comparison with Databases – Pig Latin – User-Define Functions – Data Processing Operators – Installing and Running Hive – Hive QL – Tables – Querying Data – User-Defined Functions – Oracle Big Data. (SLE: Installing and Running Hive)

Text Books:
1. Fundamentals of DBMS – RamezElmasri and Navathe, Addison Wesley, 5th edition, 2009.
2. Michael Minelli, Michehe Chambers, "Big Data, Big Analytics: Emerging Business Intelligence and Analytic Trends for Today's Business", 1st Edition, AmbigaDhiraj, Wiely CIO Series, 2013.
3. ArvindSathi, "Big Data Analytics: Disruptive Technologies for Changing the Game", 1st Edition, IBM Corporation, 2012.
4. Bill Franks, "Taming the Big Data Tidal Wave: Finding Opportunities in Huge Data Streams with Advanced Analytics", 1st Edition, Wiley and SAS BusinessSeries, 2012.
5. Tom White, "Hadoop: The Definitive Guide", 3rd Edition, O'reilly, 2012.

References:
1. Introduction to DBMS – Date C.J, Addison Wesley, 3rd edition, 1981.

Semester-II

Additive Manufacturing

ME-AR204A	Additive Manufacturing	L-T-P	3-0-0	3 Credits

Pre-Requisites: None

Mid Semester 20 Marks	Continuous Assessment 20 Marks	End-Semester Exam 60 Marks	Total 100 Marks

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

CO1	
CO2	
CO3	
CO4	
CO5	

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1												
CO2												
CO3												
CO4												
CO5												

Detailed Syllabus:

Unit I: Introduction
[8 L]

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.

Unit II: Additive Manufacturing Processes
[8 L]

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), 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).

Unit III Additive Manufacturing Machines and Systems

[8 L]

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.

Unit IV: Pre-Processing in Additive Manufacturing
[8 L]

Preparation of 3D-CAD model, 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.

Unit V: Post-Processing in Additive Manufacturing
[8 L]

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.

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

REFERENCE BOOK:
1. Liou L.W. and Liou F.W., "Rapid Prototyping and Engineering applications: A tool box for prototype development", CRC Press, 2007
2. Kamrani A.K. and 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 International Publishing AG 2018
4. Ehsan Toyserkani, Amir Khajepour, Stephen F. Corbin, "Laser Cladding", CRC Press, 2004

Semester-II
Manufacturing Automation

ME-AR204B	**Manufacturing Automation**	**L-T-P**	**3-0-0**	**3 Credits**

Pre-Requisites: None

Mid Semester 20 Marks	Continuous Assessment 20 Marks	End-Semester Exam 60 Marks	Total 100 Marks

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

CO1	Understand the concept of automation and human factors
CO2	Designing a Pneumatic and Hydraulic system for a given application
CO3	Demonstrate the use of different sensors for automation
CO4	Design automation systems for a given application
CO5	Understand the circuit optimization techniques

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	2	2		1						2
CO2	1	1	3	3		2						1
CO3	2	2	2									1
CO4	2	2	3	3								1
CO5	3	3	2	1		1						1

Course Contents:

Unit I

Product cycle, manufacturing functions, types of automation, degree of automation, technical, economic and human factors in automation.

Unit II

Technologies- mechanical, electrical, hydraulic, pneumatic, electronic, hybrid systems, comparative evaluation.

Unit III

Development of small automation systems using mechanical devices, synthesis of hydraulic circuits.

Unit IV

Circuit optimization techniques, illustrative examples of the above types of systems.

Unit V

Industrial logic control systems logic diagramming, programmable controllers.

Unit VI

Applications, designing for automation, cost-benefit analysis.

TEXTS / REFERENCES:

1. A.N.Gavrilov, *Automation and Mechanization of Production Processes in Instrument Industry*, Pergaman Press, Oxford, 1967.
2. G.Pippengerm, *Industrial Hydraulics*, MGH, New York, 1979.
3. F.Kay , *Pneumatics for Industry*, The Machining Publishing Co., London,1969.
4. A. Ray, *Robots and Manufacturing Assembly*, Marcel Dekker, New York, 1982.

Semester-II

Soft Computing Techniques

ME-AR204C	Soft Computing Techniques	L-T-P	3-0-0	3 Credits

Pre-Requisites: None

Mid Semester 20 Marks	Continuous Assessment 20 Marks	End-Semester Exam 60 Marks	Total 100 Marks

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

CO1	Classify different optimization and evolutionary algorithms.
CO2	Apply optimization techniques to real life problems.
CO3	Learn and apply neural network prediction algorithm to solve engineering problems.
CO4	Understand and apply fuzzy based logic function for predicting results.
CO5	Acquire and use knowledge of genetic algorithm to optimize real life problems.
CO6	Study different hybrid soft computing methods and its applications.

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2		2							1		2
CO2	2	2	2	2						1		2
CO3	2	2	2	2						1		
CO4	2	2	2	2						1		
CO5	2	2	2	2						1		
CO6	2	2	2	2						1		1

Unit I: Introduction

Soft Computing: Introduction of soft computing, Evolutionary Algorithms vs. Convectional optimization techniques, various types of soft computing techniques, applications of soft computing.

Artificial Intelligence: Introduction, Various types of production systems, characteristics of production systems, breadth first search, depth first search techniques, other Search Techniques like hill Climbing, Best first Search, A* algorithm, AO* Algorithms and various types of control strategies. Knowledge representation issues, Prepositional and predicate logic, monotonic and non-monotonic reasoning, forward Reasoning, backward reasoning.

Unit II: Optimization Concepts

Objective functions, constraints, Search space, local optima, global optima, fitness functions, search techniques, etc.

Unit III: Neural Networks

Artificial neural network: Introduction, characteristics- learning methods – taxonomy – Evolution of neural networks- basic models – important technologies – applications.

McCulloch-Pitts neuron – linear separability – hebb network – supervised learning network: perceptron networks – adaptive linear neuron, multiple adaptive linear neuron, BPN, RBF, TDNN- associative memory network: auto-associative memory network, hetero-associative memory network, BAM, hopfield networks, iterative autoassociative memory network & iterative associative memory network – unsupervised learning networks: Kohonenself organizing feature maps, LVQ – CP networks, ART network.

Unit IV: Fuzzy Logic

Fuzzy logic: Introduction – crisp sets- fuzzy sets – crisp relations and fuzzy relations: cartesian product of relation – classical relation, fuzzy relations, tolerance and equivalence relations, non-iterative fuzzy sets.

Membership functions: features, fuzzification, methods of membership value assignments-Defuzzification: lambda cuts – methods – fuzzy arithmetic and fuzzy measures: fuzzy arithmetic – extension principle – fuzzy measures – measures of fuzziness -fuzzy integrals – fuzzy rule base and approximate reasoning : truth values and tables, fuzzy propositions, formation of rules-decomposition of rules, aggregation of fuzzy rules, fuzzy reasoning-fuzzy inference systems-overview of fuzzy expert system-fuzzy decision making.

Unit V: Genetic Algorithm

Genetic algorithm- Introduction – biological background – traditional optimization and search techniques – Genetic basic concepts.

Genetic algorithm and search space – general genetic algorithm – operators – Generational cycle – stopping condition – constraints – classification genetic programming – multilevel optimization – real life problem- advances in GA.

Unit VI: Hybrid Soft Computing Techniques & Applications

Neuro-fuzzy hybrid systems – genetic neuro hybrid systems – genetic fuzzy hybrid and fuzzy genetic hybrid systems – simplified fuzzy ARTMAP – Applications: A fusion approach of multispectral images with SAR, optimization of traveling salesman problem using genetic algorithm approach, soft computing based hybrid fuzzy controllers.

TEXTS/REFERENCES:

1. J.S.R.Jang, C.T. Sun and E.Mizutani, "Neuro-Fuzzy and Soft Computing", PHI /Pearson Education 2004.
2. S.N.Sivanandam and S.N.Deepa, "Principles of Soft Computing", Wiley India Pvt Ltd, 2011.
3. S.Rajasekaran and G.A.Vijayalakshmi Pai, "Neural Networks, Fuzzy Logic and Genetic Algorithm: Synthesis & Applications", Prentice-Hall of India Pvt. Ltd., 2006.
4. George J. Klir, Ute St. Clair, Bo Yuan, "Fuzzy Set Theory: Foundations and Applications" Prentice Hall, 1997.

5. David E. Goldberg, "Genetic Algorithm in Search Optimization and Machine Learning" Pearson Education India, 2013.
6. James A. Freeman, David M. Skapura, "Neural Networks Algorithms, Applications, and Programming Techniques, Pearson Education India, 1991.
7. Simon Haykin, "Neural Networks Comprehensive Foundation" Second Edition, Pearson Education, 2005.

Semester-II

CAD-CAE

ME-AR204D	CAD-CAE	L-T-P	3-0-0	3 Credits

Course Pre-requisites: Numerical Methods & Computational Techniques (PC3), Structured or Object Oriented Programming (FORTRAN / C / C++ / Java / VB)

Mid Semester 20 Marks	Continuous Assessment 20 Marks	End-Semester Exam 60 Marks	Total 100 Marks

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

CO1	Demonstrate - Polynomial and spline interpolation, Bezier curves, B-splinesto surfaces representation, patches and composite surfaces.
CO2	Design and create Solid model assembly of thermal and fluid engineering system in CAD software.
CO3	Analyse simple Engineering problem by selecting appropriate Mesh generation.
CO4	Modeling and Meshing of Thermal and Fluid Flow equipment in CAD.
CO5	Simulate and demonstrate Thermal and Fluid systems by using ANSYS, EES, MATLAB etc.
CO6	Understand and simulate computer aided manufacturing.

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2											
CO2		1		1	1							
CO3		2		1								
CO4	1	1		1								
CO5	1	1		3								
CO6	1	1										

Course Contents:

Unit I

Overview of CAD Applications, Curves - Polynomial and spline interpolation, Bezier curves, B-splines, Introduction to surfaces representation, patches and composite surfaces [~3 hours] Solid Modeling: Representation of Solids, Topology, Wireframe, Boundary representation (B-Rep), CSG, Solid modeling operations [~3 hours]

Unit II

Computer Graphics: Mathematical principles for 2D and 3D visualization, Matrix transformations, Modeling, viewing, projection and rendering, OpenGL graphics library [~3 hours] Meshing – Mesh topology, Data structures, Introduction to Mesh generation algorithms, Surface meshes, Element types and quality criteria [~2 hours]

Unit III

CAD data formats and exchange [~1 hour]

Hands-on lab sessions: Modeling and Meshing of Thermal and Fluid Flow equipment [~6 hours]

Unit IV

Computer Aided Engineering: Lab simulations for Thermal and Heat Transfer [~3 hours]

Unit V

Computational Fluid Dynamics: Lab simulations for Fluid Flow [~3 hours]

Unit VI

Computer Aided Manufacturing - CAD/CAM data exchange, CAD/CAM integration,

TEXTS / REFERENCES:

- Grover, M.P., Zeemer, CAD/CAM/CIM, Prentice Hall, India
- Reddy J. N., Introduction to Finite Element Methods, McGraw Hill Education; 3 edition
- I. Zeid, Mastering CAD/CAM, McGraw Hill Education; 2 edition

Semester-II

Process Control Automation

ME-AR204E	Process Control Automation	L-T-P	3-0-0	3 Credits

Pre-Requisites: None

Mid Semester 20 Marks	Continuous Assessment 20 Marks	End-Semester Exam 60 Marks	Total 100 Marks

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

CO1	
CO2	
CO3	
CO4	

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1												
CO2												
CO3												
CO4												

Course Contents:

Unit I: Process Modeling

Introduction to Process control and process instrumentation-Hierarchies in process control systems-Theoretical models-Transfer function-State space models-Time series models-Development of empirical models from process data-chemical reactor modeling-. Analysis using softwares

Unit II: Feedback &Feedforward Control

Feedback controllers-PID design, tuning, trouble shooting, Cascade control, Selective control loop, Ratio control.

Unit III: Frequency Response

Control system design based on Frequency response Analysis, Direct digital design, Feed-forward and ratio control. State feedback control. LQR problem, Pole placement.

Unit IV: Software Simulations of control system

Simulation using softwares, Control system instrumentation, Control valves, Codes and standards, Preparation of P& I Diagrams.

Unit V: Advanced process control

Multi-loop and multivariable control, Process Interactions, Singular value analysis, tuning of multi loop PID control systems, decoupling control, strategies for reducing control loop interactions, Real-time optimization.

Unit VI: Plant Control

Model predictive control-Batch Process control-Plant-wide control & monitoring- Plant wide control design- Instrumentation for process monitoring-Statistical process control- Introduction to Fuzzy Logic in Process Control-Introduction to OPC.

Introduction to environmental issues and sustainable development relating to process industries. Comparison of performance different types of control with examples on softwares

References

1. Seborg, D.E., T.F. Edgar, and D.A. Mellichamp, Process Dynamics and Control, John Wiley , 2004
2. Johnson D Curtis, Instrumentation Technology, (7th Edition) Prentice Hall India, 2002.
3. Bob Connel, Process Instrumentation Applications Manual, McGrawHill, 1996.
4. Edgar, T.F. & D.M. Himmelblau, Optimization of Chemical Processes, McGrawHill Book Co, 1988.
5. Macari Emir Joe and Michael F Saunders, Environmental Quality Innovative Technologies

Semester-II

Internet of Things

ME-AR204F	Internet of Things	L-T-P	3-0-0	3 Credits

Pre-Requisites: None

Mid Semester 20 Marks	Continuous Assessment 20 Marks	End-Semester Exam 60 Marks	Total 100 Marks

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

CO1	
CO2	
CO3	
CO4	
CO5	

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1												
CO2												
CO3												
CO4												
CO5												

Course Contents:

Unit I: Fundamentals of IOT

Introduction to Internet of Things, Emerging Trends, Economic Significance, Technical Building Blocks, Physical design of IoT, Logical design of IoT, Sensors and actuators, Introduction to IOT networking: Gateways and routing, IoT Protocols, IoT enabling technologies, IoT Issues and Challenges, IoT Security and privacy, Applications.

Unit II: Implementation of IoT with Arduino

Introduction to arduino, arduino board overview, Programming environment, Simple assignments using arduino, Integration of Sensors and Actuators with Arduino, Sending data to Cloud, analysis using any IoT platform.

Unit III: Implementation of IoT with Raspberry Pi

Introduction to Raspberry Pi, Raspberry Pi board overview, Programming environment, introduction to python programming, Simple assignments using Raspberry Pi, Integration of Sensors and Actuators with Raspberry Pi, Sending data to cloud, analysis of data using any IoT

platform.

Unit IV: Basic Networking

Basics of Wireless Networking, Introduction to ESP8266 Wi-Fi Module, Various Wi-Fi library, Web server- introduction, installation, configuration, Posting sensor(s) data to web server, communication protocols.

Unit V: Technological Aggregation & Case Studies

Modern trends in IOT: Wearable, industrial standards, Open Data Management & API. Case studies, connected use cases in Real-life/Thematic areas – Smart Homes/Buildings, Smart Cities, Smart Industry, and Smart Medical care, Smart Automation etc.

Text Book:

1. Arshdeep Bahga, Vijay Madisetti,, Internet of Things, A hands-on approach, Universities Press
2. Honbo Zhou, The Internet of Things in the Cloud: A Middleware Perspective, CRC Press, 2012
Reference

Reference Book:

1. David Easley and Jon Kleinberg, Networks, Crowds, and Markets: Reasoning About a Highly Connected World, Cambridge University Press, 2010
2. Lyla B. Das, Embedded Systems: An Integrated Approach, Pearson
3. Dieter Uckelmann, Mark Harrison, Florian Michahelles, Architecting the Internet of Things, Springer, 2011
4. Olivier Hersent, Omar Elloumi and David Boswarthick, The Internet of Things: Applications to the Smart Grid and Building Automation, Wiley, 2012
5. Olivier Hersent, David Boswarthick, Omar Elloumi , The Internet of Things – Key applications and Protocols, Wiley, 2012
6. Barrie Sosinsky, Cloud Computing Bible, Wiley-India, 2010.
7. Adrian McEwen, Hakim Cassimally, Designing the Internet of Things, Wiley, 2014

Semester-II

Research Methodology

ME-AR205A	Research Methodology	L-T-P	3-0-0	3 Credits

Pre-Requisites: None

Mid Semester 20 Marks	Continuous Assessment 20 Marks	End-Semester Exam 60 Marks	Total 100 Marks

Course Outcomes: At the end of the course the student will be able to:

CO1	Understand and Describe importance of research.
CO2	Classify and select appropriate resources for Research.
CO3	Analyze the contents of literature and identify further scope.
CO4	Formulate a Research Problem.
CO5	Develop effective written and oral Presentation skills.

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2		3				1		3			2
CO2	2		2	1			1		1			2
CO3	2		3	3			1		1	2		2
CO4	2	3	3	2					2	2		2
CO5	2		1	3			3					3

Course contents:

Unit I

Research Concepts – concepts – meaning – objectives – motivation. Types of research – descriptive research – conceptual research – theoretical research – applied research – experimental research.

Unit II

Research process – Criteria for good research – Problems encountered by Indian researchers. Formulation of Research Task – Literature Review – Importance & Methods – Sources – Quantification of Cause Effect Relations – Discussions– Field Study – Critical Analysis of Facts Generated

Unit III

Hypothetical proposals for future development and testing, selection of Research task.

Unit IV

Mathematical modelling and simulation – Concepts of modelling – Classification of mathematical models – Modelling with – Ordinary differential equations – Difference equations – Partial differential equations – Graphs – Simulation – Process of formulation of model based on simulation.

Unit V

Interpretation and report writing – Techniques of interpretation – Precautions in interpretation – Significance of report writing – Different steps in report writing – Layout of research report – Mechanics of writing research report – Layout and format – Style of writing – Typing – References – Tables – Figures – Conclusion – Appendices.

Texts/References

1. J.W Bames, Statistical Analysis for Engineers and Scientists, McGraw Hill, N.York
2. Schank Fr., Theories of Engineering Experiments, Tata Mc Graw Hill Publication.
3. C. R. Kothari, Research Methodology, New Age Publishers.
4. Willktnsion K. L, Bhandarkar P. L, Formulation of Hypothesis, Himalaya Publication.

Semester-II

Numerical Methods & Computational Techniques

ME-AR205B	Numerical Methods & Computational Techniques	L-T-P	3-1-0	4 Credits

Pre-Requisites: None

Mid Semester	Continuous Assessment	End-Semester Exam	Total
20 Marks	20 Marks	60 Marks	100 Marks

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

CO1	Solve a set of algebraic equations representing steady state models formed in engineering problems
CO2	Fit smooth curves for the discrete data connected to each other or to use interpolation methods over these data tables
CO3	Predict the system dynamic behavior through solution of ODEs modeling the system
CO4	Solve PDE models representing spatial and temporal variations in physical systems through numerical methods.
CO5	Demonstrate proficiency of using MATLAB,VB,ANSYS,EES etc.,

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1		2	1									
CO2			1									
CO3	1					1						
CO4		1		2								
CO5		1		1								
CO6		2	1	3								2

Course Contents:

Unit I

Introduction to Numerical Analysis: Objectives, Mathematical Modeling, Programming Concepts, MATLAB, Computational Accuracy, Precision, Truncation Errors, Taylor Series [~4 hours] Curve fitting and Regression, Interpolation, Fourier Series concepts [~3 hours]

Unit II

Roots of equations: Bisection, False position, Fixed Point Iteration, Newton-Raphson, Secant methods, Roots of polynomials [~3 hours] Linear Algebraic Equations, Gauss Elimination [~2 hours]

Unit III

Non-linear Systems of Equations, Gauss-Jordan, LU Decomposition and Matrix Inversion, Gauss-Seidel, Optimization concepts [~5 hours]

Unit IV

Numerical Integration: Trapezoidal and Simpson's Rules, Gaussian Quadrature [~3 hours]
Numerical Differentiation and finite-difference approximations [~2 hours]

Unit V

Ordinary Differential Equations: Euler's and Runge-Kutta Methods, Boundary-Value, Eigen value and Eigen vector Problems [~4 hours]

Unit VI

Partial Differential Equations: Elliptic Equations, Laplace Equation and Boundary Conditions, Control Volume Approach, Parabolic Equations, Explicit and Implicit Methods, Crank-Nicolson, Introduction to Finite Element Methods [~4 hours]

TEXTS / REFERENCES:

1. Steven C. Chapra and Raymond P. Canale, Numerical Method for Engineers, 6th Edition, McGraw-Hill, 2010.
2. S.S. Sastry, Introductory Methods of Numerical Analysis, 5th Edition, PHI Learning, 2012
3. S. P. Venkateshan, Computational Methods in Engineering, 1st Edition, Academic Press, 2013
4. S.K. Gupta, Numerical Methods for Engineers, New Age International, 2009
5. Gilbert Strang, Computational Science and Engineering, Wellesley-Cambridge, 2007
6. K. Atkinson and W. Han, Elementary Numerical Analysis, 3rd Edition, Wiley-India, 2004.
7. J. D. Hoffman and Steven Frankel, Numerical Methods for Engineers and Scientists, 2nd Edition, McGraw-Hill, 2001 S. D. Conte and Carl de Boor, Elementary Numerical Analysis - An Algorithmic Approach, 3rd Edition, McGraw-Hill, 1980.

Mini Project

ME-AR206	Mini Project	L-T-P	0-0-4	2 Credits

Pre-Requisites: Previously studied course subjects.

Continuous Assessment 50 Marks	PR/OR 50 Marks	Total 100 Marks

Course Outcomes: At the end of the course the student will be able to:

CO1	Identify methods and materials to carry out experiments/develop code.
CO2	Reorganize the procedures with a concern for society, environment and ethics.
CO3	Analyze and discuss the results to draw valid conclusions.
CO4	Prepare a report as per recommended format and defend the work
CO5	Explore the possibility of publishing papers in peer reviewed journals/conference proceedings.

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	2	1		2	2	1	1	2	2	1	2
CO2	1	1	2	2			2	2	1	2	1	2
CO3	2	2		3					2	2		1
CO4				2				2	2	3		1
CO5		1		2	2			2	2	3		1

Objectives:

To train students in identification, analysis, finding solutions and execution of live engineering and managerial problems. It is also aimed to enhance the capabilities of the students for group activities. Individual students are required to choose a topic of their interest. The subject content of the mini project shall be from emerging / thrust areas, topics of current relevance having researchaspects or shall be based on industrial visits. Students can also choose live problems from manufacturing organizations as their mini project. At the end of the semester, the students should submit a report duly authenticated by the respective guide, to the head of the department.

Mini Project will have internal marks 50 and Semester-end examination marks 50.

Internal marks will be awarded by respective guides as per the stipulations given below.
Attendance, regularity of student (20 marks)
Individual evaluation through viva voce / test (30 marks)
Total (50 marks)

Semester end examination will be conducted by a committee consisting of three faculty members. The students are required to bring the report completed in all respects duly authenticated by the respective guide and head of the department, before the committee. Students individually will present their work before the committee. The committee will evaluate the students individually and marks shall be awarded as follows.
Report = 25 marks
Concept/knowledge in the topic = 15 marks
Presentation = 10 marks
Total marks = 50 marks

Semester -II

Seminar-I

ME-AR207	**Seminar-I**	**L-T-P**	**0-0-4**	**2 Credits**

Pre-Requisites: Previously studied course subjects.

Continuous Assessment 50 Marks	PR/OR 50 Marks	Total 100 Marks

Course Outcomes: At the end of the course the student will be able to:

CO1	Identify and compare technical and practical issues related to the area of course specialization.
CO2	Outline annotated bibliography of research demonstrating scholarly skills.
CO3	Prepare a well-organized report employing elements of technical writing and critical thinking.
CO4	Demonstrate the ability to describe, interpret and analyze technical issues and develop competence in presenting.

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	2	1		1	2		2	2	2	1	2
CO2		2				2		1	2	1		1
CO3						1	1	2	2	2		2
CO4	1	2	1	1		1	1	1	2	1		1

Objective:

To assess the debating capability of the student to present a technical topic. Also, to impart training to a student to face audience and present ideas and thus creating self-esteem, self-confidence and courage that are essential for an engineer. Individual students are required to choose a topic of their interest from automation and robotics related topics preferably from outside the M.Tech syllabus or an extension of syllabus and give a seminar on that topic for about 30 minutes. The Seminar can also be a case study from a automation and robotics. A committee consisting of at least three faculty members shall assess the presentation of the seminar and award marks to the students. Each student shall submit two copies of a write up of his / her seminar topic. One copy shall be returned to the student after duly certifying it by the Chairman of the assessing committee and the other will be kept in the departmental library. Internal continuous assessment marks are awarded based on the relevance of the topic, presentation skill, quality of the report and participation.

Semester-III

Project Management and Intellectual Property Rights

ME-AR301	Project Management and Intellectual Property Rights	L-T-P	0-0-0	2 Credits

Pre-Requisites: None

Continuous Assessment 50 Marks	PR/OR 50 Marks	Total 100 Marks

Course Outcomes: At the end of the course the student will be able to:

CO1	Enumerate and demonstrate fundamental terms such as copy-rights ,Patents ,Trademarks etc.,
CO2	Interpret and follow Laws of copy-rights, Patents, Trademarks and various IP registration Processes to register own project research.
CO3	Exhibit the enhance capability to do economic analysis of IP rights, technology and innovation related policy issues and firms' commercial strategies.
CO4	Develop awareness at all levels (research and innovation) of society to develop patentable technologies.
CO5	Apply trade mark law, copy right law, patent law and also carry out intellectual property audits
CO6	Manage and safeguard the intellectual property and protect it against unauthorized use

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	1					1		1			
CO2	1		2				1		2			2
CO3						1		1				
CO4						1			1			
CO5			1						1			1
CO6												

Course Contents:

A. Project Management:

Unit-I

Introduction to Project management**:** Characteristics of projects, Definition and objectives of Project Management, Stages of Project Management, Project Planning Process, Establishing

Project organization. Work definition: Defining work content, Time Estimation Method, Project Cost Estimation and budgeting, Project Risk Management, Project scheduling and Planning Tools: Work Breakdown structure, LRC, Gantt charts, CPM/PERT Networks.

Unit-II

Developing Project Plan (Baseline), Project cash flow analysis, Project scheduling with resource constraints: Resource Leveling and Resource Allocation. Time Cost Trade off: Crashing Heuristic.

Unit-III

Project Implementation: Project Monitoring and Control with PERT/Cost, Computers applications in Project Management, Contract Management, and Project Procurement Management. Post-Project Analysis.

B. IPR:

Unit-IV

Introduction to IPR; Overview & Importance; IPR in India and IPR abroad; Patents ;their definition; granting; infringement ;searching & filing; Utility Models an introduction;

Unit-V

Copyrights; their definition; granting; infringement; searching & filing, distinction between related and copy rights; Trademarks, role in commerce, importance, protection, registration; domain names;

Unit-VI

Industrial Designs ; Design Patents; scope; protection; filing infringement; difference between Designs & Patents' Geographical indications , international protection; Plant varieties; breeder's rights, protection; biotechnology& research and rights managements; licensing, commercialization; ; legal issues, enforcement ;Case studies in IPR.

TEXT BOOKS/REFERENCES:

1. Shtub,BardandGloberson,ProjectManagement:Engineering,Technology,andImplementation,Prentice Hall, India
2. Lock, Gower, Project Management Handbook.
3. Prabuddha Ganguli, IPR published by Tata McGraw Hill 2001

Semester-III

Project Stage -I

ME-AR302	Project Stage -I	L-T-P	0-0-0	10 Credits

Pre-Requisites: Previously studied course subjects.

Continuous Assessment 50 Marks	PR/OR 50 Marks	Total 100 Marks

Course Outcomes: At the end of the course the student will be able to:

CO1	Identify methods and materials to carry out experiments/develop code.
CO2	Reorganize the procedures with a concern for society, environment and ethics.
CO3	Analyze and discuss the results to draw valid conclusions.
CO4	Prepare a report as per recommended format and defend the work
CO5	Explore the possibility of publishing papers in peer reviewed journals/conference proceedings.

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	2	1		2	2	1	1	2	2	1	2
CO2	1	1	2	2			2	2	1	2	1	2
CO3	2	2		3					2	2		1
CO4				2				2	2	3		1
CO5		1		2	2			2	2	3		1

Objective:

To improve the professional competency and research aptitude by touching the areas which otherwise not covered by theory or laboratory classes. The project work aims to develop the work practice in students to apply theoretical and practical tools/techniques to solve real life problems related to industry and current research.

The project work can be a design project, experimental project, computer simulation project or an empirical study involving data collection and analysis from automation or robotic organizations. The topic should be on automation and robotics or any of the topics related with automation and robotics. The project work is allotted individually on different topics. The students shall be encouraged to do their project work in the parent institute. If found essential they may be permitted to continue their project outside the parent institute subject to the conditions of M.Tech regulations. Department will constitute an Evaluation Committee to review the project work. The Evaluation committee consists of at least three faculty members

of which internal guide and another expert in the specified area of the project shall be two essential members. The student is required to undertake the master's research project phase-I during the third semester and the same is continued in the 4thsemester (Phase-II). Phase-I consists of preliminary thesis work, two reviews of the work and the submission of preliminary report. First review would highlight the topic, objectives, methodology and expected results. Second review evaluates the progress of the work, preliminary report and scope of the work which is to be completed in the 4th semester.

Semester-IV

Project Stage-II

ME-AR401	Project Stage-II	L-T-P	0-0-0	20 Credits

Pre-Requisites: Previously studied course subjects.

Continuous Assessment 100 Marks	PR/OR 100 Marks	Total 200 Marks

Course Outcomes: At the end of the course the student will be able to:

CO1	Identify methods and materials to carry out experiments/develop code.
CO2	Reorganize the procedures with a concern for society, environment and ethics.
CO3	Analyze and discuss the results to draw valid conclusions.
CO4	Prepare a report as per recommended format and defend the work
CO5	Explore the possibility of publishing papers in peer reviewed journals/conference proceedings.

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	2	1		2	2	1	1	2	2	1	2
CO2	1	1	2	2			2	2	1	2	1	2
CO3	2	2		3					2	2		1
CO4				2				2	2	3		1
CO5		1		2	2			2	2	3		1

Objectives:

To improve the professional competency and research aptitude by touching the areas which otherwise not covered by theory or laboratory classes. The project work aims to develop the work practice in students to apply theoretical and practical tools/techniques to solve real life problems related to industry and current research.

Masters Research project phase-II is a continuation of project phase-I started in the third semester. Before the end of the fourth semester, there will be two reviews, one at middle of the fourth semester and other towards the end. In the first review, progress of the project work done is to be assessed. In the second review, the complete assessment (quality, quantum and authenticity) of the thesis is to be evaluated. Both the reviews should be conducted by guide and Evaluation committee. This would be a pre-qualifying exercise for the students for getting approval for the submission of the thesis. At least one technical paper is to be prepared for possible publication in journal or conferences. The technical paper is to be submitted along with the thesis. The final evaluation of the project will be external evaluation.