Engineering Branch: Mechanical Engineering

Minor/ Honours (Specialization) Subject: Smart Manufacturing

Scheme of Instructions and Examination

Course Code	Semester	Nomenclature of the Course	Scheme of Instruction Hrs/Week			Scheme of Examination							
			L	T	P	Duration (Hrs)	Marks						Credits
							Th	IA	TW	P	O	Total	
MES410	IV	Rapid Prototyping	3	1	--	3	100	25	--	--	25	150	4
MES510	V	Industry 4.0 and Industrial Internet of Things	3	--	2	3	100	25	--	25	--	150	4
MES610	VI	PLC and SCADA	3	--	2	3	100	25	--	25	--	150	4
MES710	VII	Advanced CNC Technology	3	--	2	3	100	25	--	25	--	150	4
MES810	VIII	Robotics and Artificial Intelligence	3	--	2	3	100	25	--	25	--	150	4
		TOTAL	15	1	8	--	500	125	00	100	25	750	20

LEGEND

Abbreviation	Description
L	Lecture
T	Tutorial
P	Practical
O	Oral
Th	Theory
TW	Term Work
IA	Internal Assessment

(Back to Index)

Rapid Prototyping					
Course Code	**MES410**		**Credits**	**4**	
Scheme of Instructions (Hours / week)	**L**	**T**	**P**	**TOTAL**	
	3	**1**	**0**	**42 hrs/sem**	
Scheme of Examination TOTAL = 150 marks	**IA**	**TW**	**TM**	**P**	**O**
	25	**0**	**100**	**0**	**25**

Course Objectives:

1. To inculcate the knowledge and skills related to Rapid Prototyping technologies
2. To provide overview of selection of material, equipment and development of a Rapid Prototype for smart manufacturing in Industry 4.0

Course Outcomes:

On completing this course students will be able to:

CO 1	Understand various processes of additive manufacturing and their applications
CO 2	Select a specific material for the given application
CO 3	Select a Rapid Prototyping process for a given application
CO 4	Apply the concepts of 3D modelling and additive manufacturing to produce a component using a standard 3 D Printer

UNIT-1	**10Hrs**
Introduction to Rapid Prototyping: Introduction, Process, Classifications, Advantages, Additive v/s Conventional Manufacturing processes, CAD for Additive Manufacturing, CAD Data formats, Data translation, Data loss, STL format. **Vat Polymerization:** Principle of Working & Process parameters of Stereolithography (SLA), Digital Light Processing (DLP), Masked Stereolithography (MSLA), Lithography-based Metal Manufacturing (LMM), Light Enabled Additive Production (LEAP), Projection Micro Stereolithography (PμSL), Digital Composite Manufacturing (DCM)	
UNIT-2	**11Hrs**
Material Extrusion: Principal of Working & Process parameters of Fused Deposition Modelling (FDM) **Powder Bed Fusion**: Principle of Working & Process parameters of Selective laser sintering (SLS), selective laser melting (SLM), Electron beam melting (EBM), Direct metal laser sintering (DMLS), Multi Jet Fusion (MJF) **Material Jetting**: Principle of Working & Process parameters of Material Jetting (MJ), Nanoparticle Jetting (NPJ), BINDER JETTING: Sand Binder Jetting, Metal Binder Jetting, Plastic Binder Jetting,	
UNIT-3	**10Hrs**

Direct Energy Deposition: Principle of Working & Process parameters of Laser Engineered Net Shaping (LENS), Electron Beam Additive Manufacturing (EBAM), Direct Metal Deposition (DMD), Wire Arc Additive Manufacturing (WAAM), **Sheet Lamination:** Principle of Working & Process parameters of Laminated Object Manufacturing (LOM), Ultrasonic Consolidation (UC), Selective Lamination Composite Object Manufacturing (SLCOM), Plastic Sheet Lamination (PSL), Selective Deposition Lamination (SDL), Composite Based Additive Manufacturing (CBAM), InLay moulding, Vacuum Moulding, Silicon Moulding	
UNIT-4	**11Hrs**
Materials in additive manufacturing: Introduction, Nature of Material, Physical Properties, Chemical Properties, Mechanical Properties, Application, Processing temperature of PLA, ABS, Nylon 66, PP, PC-ABS, PEEK. **AM Applications**: 3D printing in Bioprinting tissues and organoids, Surgical Instruments, Custom made prosthetics, Dental applications. Prosthetic jaws and Implants, Blood vessels, organ printing, Tablet Printing, Automotive, Aerospace, Robotic and defence applications, 3D printing of a building Demonstration of Additive Manufacturing process and Reverse Engineering with a standard 3 D Printer by slicing STL file.	
Four assignments, one on each unit to be submitted within the given deadline.	

TEXTBOOKS	
1	**Rapid prototyping: Principles and applications**, Chua C.K., Leong K.F., and Lim C.S; Third Edition, World Scientific Publishers, 2010.
2	**Rapid Prototyping and Engineering applications: A tool box for prototype development**, Liou L.W. and Liou F.W; CRC Press, 2007.
3	**Rapid Manufacturing**, Flham D.T &Dinjoy S S; Verlog London 2001.
4	**Rapid Tooling: Technologies and Industrial Applications**, Hilton P.D. and Jacobs P.F; CRC press, 2000
5	**Fundamentals of Additive Manufacturing Technologies**, Prof. Sajan Kapi; NPTEL Course
REFERENCES	
1	**Rapid Prototyping: Theory and practice**, Kamrani A.K. and Nasr E.A; Springer, 2006
2	**Additive Manufacturing Technologies Rapid Prototyping to Direct Digital Manufacturing**, I. Gibson l D. W. Rosen l B; Stucker Springer New York Heidelberg Dordrecht, London ISBN: 978- 1-44191119-3 e- ISBN: 9781-44191120-9 DOI 10.1007/9781-44191120-9
3	**Understanding Additive Manufacturing**, Andreas Gebhardt; Hanser Publishers, 2011
4	**Additive Manufacturing Technology, rapid manufacturing**, Hari Prasad, A.V.Suresh; Cengage 2019

Industry 4.0 and Industrial Internet of Things					
Course Code	**MES510**		**Credits**	**4**	
Scheme of Instructions (Hours / week)	**L**	**T**	**P**	**TOTAL**	
	3	**0**	**2**	**42 hrs/sem**	
Scheme of Examination TOTAL = 150 marks	**IA**	**TW**	**TM**	**P**	**O**
	25	**0**	**100**	**25**	**0**

Course Objectives:

1. To provide an overview of the basic concepts of Smart Manufacturing and Internet of Things for Industry 4.0 and related technologies
2. To introduce to the standard programming tools for data analytics, machine learning and Internet of Things and interfacing IoT based applications

Course Outcomes:

On completing this course students will be able to:

CO 1	Understand the technologies like Cyber Physical Systems, Internet of Things, Data Analytics, Cloud Computing and Machine Learning which drive Industry 4.0
CO 2	Apply concepts of data analytics and machine learning for simple real-life applications
CO 3	Develop Industrial IoT based applications using Arduino/ Raspberry pi
CO 4	Implement solutions for Industry 4.0 by analysing and integrating various tools of smart manufacturing

UNIT-1	**10 Hrs**
Introduction to Industry 4.0 – Fourth Industrial Revolution, Definition and Megatrends in Industry 4.0, Design principles, Smart factory, PLM for Industry 4.0 **Industrial Internet of Things (IIoT)**: Introduction to Cyberphysical systems, Ubiquitous sensing and Advanced analytics, Data integration challenges, Smart sensor, Accessing sensors and actuators, Intel IOT device library, Futuristic industrial plant – 5C architecture for cyber physical systems, IIoT Reference Architecture-Introduction, Review of M2M communication, 3 tier architecture pattern, IIOT layer wise architecture, Sensing for manufacturing process in IIoT	
UNIT-2	**10 Hrs**
Communication in Industry 4.0: - IEEE 802.15.4, Zigbee, Wireless HART, Z wave, Bluetooth, RFID, MQTT, CoAP, LPWAN, Basics of 5G and API, Introduction to computing with Arduino & Raspberry Pi, Case studies of IIoT processing for self-driving car, AR drone-based precision agriculture, iRobot factory, Big data driven smart manufacturing, Issues with IoT Standardization **Cybersecurity:** Components, Elements, IIoT security issues, cybersecurity requirements, Challenges in IIoT, Cybersecurity for Industry 4.0, Cyber-attack detection	

Virtual Reality (VR) and Augmented Reality (AR): Introduction, Chronological order, Features, Applications, Types of AR & VR	
UNIT-3	**11 Hrs**
Big Data Analytics: Classification of digital data, Introduction to big data, Definition, Characteristics of big data, Data sources, Data acquisition, Typical data warehouse environment and Hadoop environment, Introduction to Big data analytics, Big data analytics for Industry 4.0, Cloud based methods, Types of analytics, Components of Python in data science **Data exploration:** Data pre-processing, Data quality, Data cleaning- Missing values, Binning, outliers, Data cleaning process, Data reduction- Dimensionality and numerosity reduction, Sampling, Data compression, Brief overview of data transformation strategies and data integration, Normalisation, Data visualisation- Relationship between features, Scatter plot, bar plots, histogram, box plots, Case study on data pre-processing and visualisation, Introduction to data mining	
UNIT-4	**11 Hrs**
Artificial Intelligence and Machine Learning: Introduction, Scope, Machine learning, Role of AI in Industry 4.0 & IIoT Types of ML algorithms-, Supervised and unsupervised learning, Clustering, Regression model Collaborative filtering, Association rule mining, Decision tree, applications of IIoT with ML, Introduction to Deep learning, Case study of big data analytics in an aircraft **Cloud computing in IIoT**: Introduction, Need for cloud, Cloud components, Full and para virtualisation, Cloud deployment models, Services, Applications, cloud based IIoT architecture, Industrial cloud providers- GE Predix, Siemens Mindsphere, Honeywell, Limitations, Cloud of Things, Introduction to Google cloud platform and Amazon Web services, fog computing, Industrial data management using Hadoop **IIoT and Industry 4.0 Case studies**: Smart factory applications (Kuka/Airbus), IoT in healthcare (oxygen saturation monitor), Predictive maintenance and asset condition monitoring with AWS IoT, IoT in oil and gas/pharma industry	

TEXTBOOKS	
1	**Introduction to Industrial Internet of Things and Industry 4.0**, Sudip Misra; NPTEL
2	**Introduction to Industrial Internet of Things and Industry 4.0**, S. Misra, C. Roy, and A. Mukherjee; 2020, CRC Press, 2020
3	**Data Mining Concepts and Techniques**, Jiwawei Han, Micheline Kamber, Jan Pei; Elsevier, 3rd Edition
REFERENCES	
1	**Industry 4.0: The Industrial Internet of Things**, Alasdair Gilchrist; Apress, 1st Edition
2	**Introduction to IoT**, S. Misra, A. Mukherjee, and A. Roy; Cambridge University Press, 2020.
3	**Big data analytics**, Seema Acharya, Subhashini Chellappan; Wiley, 2nd edition, 2019
4	**Fundamentals of Machine Learning for Predictive Data Analytics: Algorithms, Worked Examples, and Case Studies** , John D. Kelleher , Brian Mac Namee, Aoife D'Arcy; The MIT Press, 2015

5	**Cloud Computing**, Kris Jamsa; Jones and Bartlett Learning, Indian student Edition
6	**Cloud Computing , A Practical Approach**, Anthony Velte, Toby Velte, Robert Elsenpeter; McGraw Hill Education, Indian Edition
7	**Industrial Internet of Things: Cyber manufacturing Systems**, Sabina Jeschke, Christian Brecher, Houbing Song, Danda B. Rawat; Springer
8	**Learning Python**, Mark Lutz; O‟Reilly Publications
9	https://aws.amazon.com/
10	https://scipy.github.io

List of Experiments for Practical

Note: Any 8 Exercises/Experiments to be performed

I. IIOT
Tools: Arduino/Raspberry Pi

1. Write a program to interface Push button/Digital sensor (IR/LDR) and to turn ON LED /Buzzer for 1 sec after every 2 seconds.

2. Write a program to print temperature and humidity readings and generate weekly reports using SQL

3. Write a program to interface motor using relay turn ON motor when push button is pressed.

4. Write a program to interface OLED with Arduino/Raspberry Pi and write a program to print temperature and humidity readings on it.

5. Write a program to send sensor data to smartphone after ever 2 secs and turn ED ON/OFF when 1‟/‟0‟ is received from smartphone using Bluetooth

6. Write a program on Arduino/Raspberry Pi to upload & retrieve temperature and humidity data from thing speak cloud.

II. Data analytics
Tools: Python/ R programming

1, Data preparation and cleaning
2. Descriptive Statistics, Correlation, Simple Linear Regression
3. Data Visualization using matplotlib & Seaborn

III. AI/ML
Tools: Python/R Programming
1. Write a programme to predict the class of the flower based on available attributes.

Programmable Logic Controllers and SCADA					
Course Code	**MES610**		**Credits**	**4**	
Scheme of Instructions (Hours / week)	**L**	**T**	**P**	**TOTAL**	
	3	**0**	**2**	**42 hrs/sem**	
Scheme of Examination TOTAL = 150 marks	**IA**	**TW**	**TM**	**P**	**O**
	25	**0**	**100**	**25**	**0**

Course Objectives:

This course aims to familiarize with PLC and its programming. Theoretical inputs to architecture, instruction set, ladder logic programming, various industrial applications and the use of PLC

Course Outcomes:

On completing this course students will be able to:

CO 1	Recognize the fundamental principles of PLC and SCADA
CO 2	Understand the various elements and concepts of Ladder Logic Programming.
CO 3	Develop ladder program for sequential and continuous process
CO 4	Interface analog and digital input/ output devices with PLC using different communication protocol.

UNIT-1	**10 Hrs**
Introduction to PLC: Definition, advantages and Importance of PLC, Evolution history of PLC, architecture and block diagram, solid state memory; the processor; I/O modules; power supplies. PLC advantage & disadvantage; PLC versus Computers, PLC Application. **PLC Hardware:** The I/O section, Discrete I/O Modules, Analog I/O Modules, Special I/O Modules, I/O specifications, The CPU, Memory design, Memory Types, Programming Devices, Selection of wire types and size.	
UNIT-2	**10 Hrs**
PLC Programming: Basic Ladder logic, logic functions, electrical wiring diagram, scan cycle. Programming languages for PLC, PLC module addressing, registers basics, basic relay instructions, timer-counter instructions, arithmetic functions, comparison functions, data handling, data move functions, input-output instructions, sequencer instructions, Case studies.	
UNIT-3	**12 Hrs**
Timers: Mechanical Timing relay, Timer instructions, ON delay timer instruction, Off-Delay timer instruction, Retentive Timer, Cascading Timers, examples of timer function industrial application; industrial process timing application. **Counters:** Counter Instructions, Up-counter, down counter, UpDown counter, Cascading counters, Incremental encoder counter applications, Combining counter	

and timer functions, High Speed counter instruction, examples of counter function industrial application.	
UNIT-4	**10 Hrs**
PLC Networking: Introduction, Levels of Industrial Control, Types of Networking, Network communications, Interface Standard, Modbus and Modbus plus Protocols, CC-Link overview, HART, AS-interface (AS-i), DeviceNet overview, ProfiBus PA/DP/FMS protocol, Foundation Fieldbus, Industrial Ethernet overview, TCP/IP overview, OPC server client. **SCADA:** Introduction, Open system: Need and advantages, Building blocks of SCADA systems, Remote terminal unit (RTU): Evolution of RTUs, Components of RTU, Communication subsystem, Logic subsystem, Termination subsystem, Testing and human-machine interface (HMI) subsystem, Power supplies.	

TEXTBOOKS/ REFERENCES	
1	**Programmable Logic Controllers, Principles and Applications**: John W. Webb, Ronold A Reis; 5th Edition, Prentice Hall of India Pvt. Ltd
2	**Programmable Logic Controllers**, Frank Petruzzula; Tata Mc-Graw Hill Edition.
3	**Programmable Logic Controllers Industrial Automation an Introduction**, Madhuchannd Mitra and Samerjit Sengupta; Penram International Publishing Pvt. Ltd.
4.	**Programmable Logic Controllers Principles and Applications**, J. R. Hackworth and F. D. Hackworth; Pearson publication
5.	**Supervisory Control and Data Acquisition**, Boyar S A; ISA Publications New Delhi
REFERENCES BOOKS:	
1	**PLC and SCADA**, J Singh, M Deswal; USP(India) Pvt Ltd.
2	**Introduction to Programmable Logic Controllers**, Dunning G; Thomson/Delmer Learning, New Delhi, 2005
3	**Industrial Automation and Process Control**, Stenerson J; PHI Learning, New Delhi

List of Experiments for Practical

Note: Any 8 Exercises/Experiments to be performed

1. Introduction to ladder programming& to implement basic logic gates.
2. Temperature Control using PLC
3. Traffic light control system using PLC
4. Bottle filling automation system using PLC
5. DC Motor Control System using PLC
6. Speed measurement using counter
7. Elevator system control using PLC
8. Car Parking system control using PLC
9. Pneumatic Sequencing using PLC
10. Pneumatic actuation with Timers and Counters using PLC
11. Temperature Control using SCADA
12. Pressure Control using SCADA

Advanced CNC Technology					
Course Code	**MES710**		**Credits**	**4**	
Scheme of Instructions (Hours / week)	**L**	**T**	**P**	**TOTAL**	
	3	**0**	**2**	**42 hrs/sem**	
Scheme of Examination TOTAL = 150 marks	**IA**	**TW**	**TM**	**P**	**O**
	25	**0**	**100**	**25**	**0**

Course Objective: This course aims to inculcate thorough knowledge of CNC programming, testing and proving the program on the CNC Machine.

Course Outcomes: After completion of the course, students would be able:

CO 1	To understand the main features and working parts of CNC machines and accessories.
CO 2	To write a CNC Program for turning operations.
CO 3	To write a CNC Program for milling operations.
CO 4	To understand the computer technologies needed to automate the inspection procedures in manufacturing.

Course Contents:

UNIT-1	**10 Hrs**
Introduction to Computer Numerical Control (CNC): Numerical control, Functions of a machine tool, Concept of numerical control, Historical Development, Definition, Advantages of CNC machine tools, Evolution of CNC, Advantages of CNC, Limitations of CNC, Features of CNC, The Machine Control Unit (MCU) for CNC, Classification of CNC Machine Tools, CNC machining centres, Classification, Features of CNC Machining Centres	
UNIT-2	**10 Hrs**
Introduction to CNC cutting tool materials and Inspection technologies: Learn different types of Cutting tool materials used in CNC machine tools, understand milling tooling system, know the need for tool pre-setting and work holding. Automated Inspection. Contact v/s noncontact inspection techniques. CMM: construction, operation and programming. Understand the Touch trigger probes and their functions used for inspection on a CNC machine tool. Applications of probing: datuming of the workpiece, workpiece dimension measurement, tool probing.	
UNIT-3	**11 Hrs**
CNC programming-Turing: Plan and optimize programs for CNC turning operations. Calculate parameters like speed feed etc. and set references for the various operations. Prepare Process plan for the lathe operations. Prepare & set CNC lathe operations and test run programmed. Execute program and inspect simple geometrical forms / standard parts	

UNIT-4	11 Hrs
CNC programming-Milling: Plan and optimize programs for CNC Milling operations. Calculate parameters like speed feed, depth of cut etc. and set a reference for the various operations. Various methods of work process like edge finding block centre etc. Prepare & set CNC Milling operations and test run programmed. Execute program and inspect simple geometrical forms / standard parts.	

TEXTBOOKS	
1	**CAD/CAM: Principals and Applications**, P. N. Rao; Tata McGraw-Hill Publishing Company Ltd.; 2e; 2004.
2	**CAD/CAM, Theory & Practice**, Ibhrahim Zeid, R. Sivasubramanium; Tata McGraw-Hill Publishing Company Ltd.; 2e; 2009.
3	**Automation, Production systems and Computer Integrated Manufacturing**, M. P. Groover; Pearsen Education Asia;2e; 2001.
REFERENCES	
1	**Numerical control & computer aided manufacturing**, T.K. Kundra, P. N. Rao, N.K. Tewari; Tata McGraw Hill
2	**CAD/CAM/CIM**, Radhakrishnan P. Subramanyan S; New Age International publishers, 1994
3	**Computer aided manufacturing**, Tien Chien Chang, Rolland Wyst; HSU Pin Wang, Pearson Education

List of Experiments for Practical

Note: Any 8 Exercises/Experiments to be performed

1. Introduction to various G-codes, M-codes and Canned Cycles for milling and turning.
2. Writing Manual CNC program for turning operation with Cut plan and finishing.
3. Writing Manual CNC program for milling operation for 2D milling cycle.
4. Generation of CNC program using CNC software for milling operations with cycles for contour, pocket, facing and slot milling.
5. Generation of CNC program using CNC software for hole making operations (drilling, boring, reaming, tapping) on machining centre.
6. Generation of CNC program using CNC software for turning operations such as facing, grooving, parting and threading.
7. Generation of CNC program using CNC software for hole making operations (drilling, boring, reaming, tapping) on turning centre.
8. Generation of mill tool paths for finishing cycles (parallel, radial, contour) on 3D surface

Experiments on Turning and milling centre

9. Introduction to CNC turning centre and modes of Operation.
10. Introduction to CNC milling centre and modes of Operation.
11. Loading CNC program from software into CNC turning centre control Panel, program testing and debugging.

12. Work Piece setup and taking offset for various types of tools.
13. Machining of workpiece on CNC turning centre.
14. Machining of workpiece on milling centre.

Robotics and Artificial Intelligence					
Course Code	**MES810**		**Credits**	**4**	
Scheme of Instructions (Hours / week)	**L**	**T**	**P**	**TOTAL**	
	3	**0**	**2**	**42 hrs/sem**	
Scheme of Examination TOTAL = 150 marks	**IA**	**TW**	**TM**	**P**	**O**
	25	**0**	**100**	**25**	**0**

Course Objectives:

1. To learn the fundamentals of robotics, sensor and drive technologies
2. To comprehend and analyze the robot arm kinematics
3. To understand integration of Arduino and Raspberry Pi boards with ROS
4. To familiarize students with Artificial Intelligence principles and techniques

Course Outcomes:

On completing this course students will be able to:

CO 1	Understand the fundamentals and peripherals of robots.
CO 2	Model forward and inverse kinematics of robot manipulators.
CO 3	Apply integration of Arduino and Raspberry Pi boards with ROS.
CO 4	Implement appropriate searching strategies for few real world environments

UNIT-1	**11 Hrs**
Fundamentals of Robotics: Basic components of robotic system, Robot anatomy, Robot Joints, Degree of freedom, Robot configurations, Robot Body-arm and Wrist motions, End effectors- Grippers and Tools, Guidelines for design for robotic gripper. **Robot Kinematics:** Spatial Descriptions: position and orientation, Transformations and Euler angle representations, Homogeneous Transformation Matrices, Forward and Inverse Kinematics of Robots, Denavit - Hartenberg representation, Forward and Inverse Kinematic solution for simple robot configurations, Velocity analysis of serial robots, Jacobian, Singularities	
UNIT-2	**10 Hrs**
Trajectory Planning: Introduction, Path versus Trajectory, Basics of Trajectory planning, Joint space and Cartesian space Trajectories **Mobile Robots**: Introduction, Key issues for locomotion, Legged mobile robots:	

Types, leg configuration and stability, Wheeled mobile robots: Wheel configuration & wheel design, Path Planning	
UNIT-3	**10 Hrs**
Robot Programming: Methods of robot programming, Motion Interpolation, Defining Positions in Space, Robot programming languages, VAL II **Robot Operating System (ROS):** ROS Basics, ROS Equation, History of ROS, Sensors and Robots Supporting ROS, ROS Architecture and Concepts, ROS Filesystem Level, ROS Computation Graph Level, ROS Community Level. Python for Robotic programming- Basic Concepts with examples **ROS Programming:** Creating ROS Workspace and Package, Using ROS Client Libraries, Programming Embedded Board using ROS-Interfacing Arduino with ROS, ROS on a Raspberry Pi.	
UNIT-4	**11 Hrs**
Artificial Intelligence: Definitions - Importance of AI, Evolution of AI - Applications of AI, Classification of AI systems with respect to environment, Intelligent Agents, Different types of agents **Problem Solving:** Problem solving agents, Example Problems, Searching for solutions, Uniformed and Informed search strategies, Heuristic Functions **Uncertainty Knowledge and Reasoning:** Definition of uncertainty, Bayes Rule - Inference, Belief Network.	

TEXTBOOKS	
1	**Industrial Robotics Technology, Programming and Applications**, M. P. Groover, M. Weiss, R. N. Nagel, N. G. Odrey; Tata McGraw Hill Education; Special Indian; 2e; 2012.
2	**Robotics: Control, Sensing, Vision and Intelligence**, Fu. K.S., Gonzalez R.C. and Lee C.S.G; Tata McGraw Hill, 2008.
3	**Introduction to Autonomous Mobile Robots**, Roland Siegwart and Illah R. Nourbakhsh; The MIT Press (2004).
4	**Robot Operating System (ROS) for Absolute Beginners: Robotics Programming Made Easy**, Lentin Joseph; 1st Edition, A Press, 2018.
5	**Artificial Intelligence - A Modern Approach**, Stuart Russell and Peter Norvig; PrenticeHall, 3rd edition, 2016.
REFERENCES	
1	**Robotics: Fundamental Concepts and Analysis**, Ghosal A; Oxford University Press, 2006.
2	**Robotics and Control**, R. K. Mittal, I J Nagrath; McGraw Hill Education; 1e; 2003
3	**Introduction to Robotics – Mechanics and Control**, Craig J.J; Pearson Prentice Hall, 2005.

4	**Introduction to Robotics**, Saha. S.K; McGraw Hill Education (India) Private Limited, 2014.
5	**Mastering ROS for Robotics Programming: Design, build, and simulate complex robots using the Robot Operating System**, Jonathan Cacace; Lentin Joseph; 2nd Edition, Packt Publishing, 2018
6	**Programming Robots with ROS: a practical introduction to the Robot Operating System**, Quigley, M., Gerkey, B. and Smart, W.D; O'Reilly Media, Inc., 2015
7	**A First Course in Artificial Intelligence**, Deepak Khemani; McGraw Hill Education (India) 2013.
8	**Beginning Robotics with Raspberry Pi and Arduino: Using python and Open CV**, J. Cicolani; 2nd edition, Apress Inc.
9	**Open CV with Python by Example: Build real world computer vision applications and develop cool demos using OpenCV for python**, P. Joshi; Packt Publishing, 2015.

List of Experiments for Practical

Note: Any 8 Exercises/Experiments to be performed

Robot Kinematics (using Robo Analyser or any other standard software)

1. Exercises on analysing Forward Kinematics of a Robotic arm
2. Exercises on analysing Inverse Kinematics of a Robotic arm

Pick and Place Programming (No simulation)

3. Exercise on Pick and place programming using VAL-II

ROS (Using Python or any other standard software)

4. Simulation of Robotic arm using ROS
5. Exercise on integrating Sensors, Microcontroller and ROS in Robotic system
6. Exercise on Path planning using Arduino-ROS

Artificial Intelligence (Using Python or any other standard software)

7. Write a program to implement Breadth First Search algorithm
8. Write a program to implement Depth First Search algorithm
9. Write a program to implement Uniform Cost Search algorithm

Machine Vision (Using OpenCV or any other standard software)

10. Study of Machine Vision system
11. Exercise on Image Acquisition and processing
12. Exercise on Feature extraction and Object recognition

(Back to Index)