M. Tech. in Robotics

***Brief Description*:** M.Tech. in Robotics is an interdisciplinary Masters Programme composed of Mechanical Engineering, Electrical/Electronics Engineering, Computer science /Information Technology Engineering, and Instrumentation Engineering. Due to increasing impact of smart systems and modernization in human life, the demand for students specialized multidisciplinary areas like robotics is growing day by day in Indian industries, defence applications, atomic energy, space research, medical research etc. The program is designed for eligible candidates interested in designing, controlling and creating robotic systems.

Eligibility:

1. The eligibility for the M.Tech. in Robotics will be Bachelor's degree in Mechanical/ Electrical/Electronics/Mechatronics/Control/Computer Science/Information Technology Aerospace/Aeronautical/Automobile/Industrial and Instrumentation Engineering etc. disciplines from recognized university.
2. This programme is open for GATE qualified civilian candidates, DRDO Scientists/Officers and Officers from Tri-services. This programme is also open to foreign nationals from the countries approved by GOI.

Organization: M. Tech in Robotics is a four-semester master's programme. There are six compulsory courses in the first semester, four compulsory and two elective subjects in the second semester. In each semester, three tests as a part of continuous evaluation and an end semester examination will be conducted for each course. M.Tech dissertation first phase evaluation will be conducted at the end of third semester and at the end of the final semester, students submit their thesis and present their project work, which is evaluated by the Internal and External examiners.

Visits to various DRDO Labs are planned to enhance student's practical understanding of the subject and provide them the opportunity to get hands on experience on various equipments and latest systems. The details of the courses offered under the programme are given below:

Semester I

Sl. No.	Course Code	Course	Contact Hours/week		Credits
			L	T/P	
1	ME 664	Introduction to Robotics	3	1	4
2	ME 665	Mechatronics	3	1	4
3	# ME 639/ ## EE 649	Introduction to Mechanisms Or Introduction to Electronics Systems	3	1	4
4	CE 696	Artificial Intelligence and Expert Systems	3	1	4
5	ME 666	Robot Sensors and Actuators and Drives	3	1	4
6	AM 607	Mathematics for Engineers	3	1	4
		Total	**18**	**06**	**24**

Note: #ME 639 for (Non – Mechanical students) &##EE 649 for (Non- Electronics students) compulsory subject.

Semester II

Sl. No.	Course Code	Course	Contact hours/week		Credits
			L	T/P	
1	ME 667	Robot Kinematics and Dynamics	3	1	4
2	ME 668	Machine vision & Image Processing for Robots	3	1	4
3	EE 620	Soc and Embedded Systems	3	1	4
4	ME 663	Robotic Path Planning and Control	3	1	4
5		Elective – I	3	1	4
6		Elective – II	3	1	4
		Total	**18**	**06**	**24**

Semester- III

S. No.	Course Code	Course	Credits		Total Credits
			L	T/P	
1	ME 651	M.Tech. Dissertation Phase I	28**		14
		Total	**28**		**14**

Semester-IV

S. No.	Course Code	Course	Credits		Total Credits
			L	T/P	
1	ME 652	M.Tech. Dissertation Phase II	28**		14
		Total	**28**		**14**

****Contact Hours / week:-**

- 1 credit in Theory/Tutorial implies one contact hour and 1 credit in Practice/ Thesis implies two contact hours.

List of Electives

Sl. No.	Course Code	Course Name(Elective I and II)
1	ME 614	Unmanned ground vehicles
2	ME 628	Design of Hydraulic and Pneumatic System
3	ME 629	Industrial Automation
4	ME 631	Product design and development
5	ME 634	Flexible Manufacturing systems
6	ME 635	CAD/CAM
7	ME 638	Field and service Robots
8	ME 642	Automatic Control System
9	ME 653	Introduction to Mobile Robotics
10	ME 655	Performance testing and Instrumentation
11	ME 669	Humaniod
		Open elective from other department

Detailed Contents

Course Name- Introduction to Robotics

Course Code - ME 664

UNIT I: Evolution of Robot, Laws of Robotics, Robot classification, Types and components of Robot, Anatomy, Robot terminology-Links, joints, DOF, Specification of a robot ,work volume, work space, work object & MTBF, Robot geometrical configuration (PPP, RPP, RRP, RRR, etc) & Selection of Robots, Control Resolution & Spatial Resolution.

UNIT II: Robot workcell, Kinamatic systems, spatial descriptions: Position, orientation and frames, Coordinate frames, Mapping between frames, translations, rotations and transformations matrices and Homogeneous Transformation Matrix.

UNIT III: Robot end effectors-classification Grippers, Types of Grippers-Mechanical, finger grippers Magnetic-vacuum/suction, Hooks, scoops and other devices, selection of grippers, gripping mechanisms, Gripper force analysis and design of Drive system for gripper, tools Characteristics and elements of End-of-Arm-Tooling.

UNIT VI: Euler angles for specifying orientation, Euler angles for roll-yaw-roll geometry, Gripper positioning by Euler angles for roll-yaw-roll geometry - Euler angles for roll - pitch - yaw geometry, Cylindrical Robot coordinates, polar Robot coordinates, calculation of cylindrical, polar coordinates,

UNIT V: Robot capabilities and applications- wheeled, tracked, legged, aerial, underwater robots, surgical robots, rehabilitation robots, humanoid robots, Nano Robots, Robotic Accidents and safety, social and environmental impact of robotics, Robot maintenance.

UNIT VI: Repetitive tasks in Industries, In hazardous environments - underwater, space, fire, handling of chemicals, radioactive substances, Tele-operation vs autonomous robots, Rescue robots, Unmanned vehicles, Robot soldiers, Kinamatics and dynamics of mobile robotics, Introduction to Robot Programming, on-line and off-line Programming, Robot Programming Languages.

Practice:
1. Mobile Robot Control and programming.
2. Robot Kinamatics Simulation Software.
3. Industrial Robot operation and programming with teach pendent.
4. Robot Studio: Programmable control of Industrial Robot.
5. Case studies.

Text Books:-

1. S.R. Deb, *Robotics Technology and flexible automation*, Tata Mc Graw Hill publishing company Ltd.
2. John J Craig, *Introduction to Robotics-Mechanics and control*, Pearson publication,2008
3. S K Saha, *Introduction to Robotics*, McGraw Hill Education(India) Private Ltd, 2014.
4. R K Mittal, I J Nagrath, *Robotics and Control*, McGraw Hill Education(India) Private Ltd, 2003.

References:

1. Francis N. Nagy, Andras Siegler, *Engineering foundation of Robotics*, Prentice Hall Inc., 1980.
2. M.P. Groover, Mitchel Weiss, *"Industrial Robotics: Technology, Programming and Applications"(2e),* McGraw Hill , 2012
3. Richard D. Klafter, Thomas. A, ChriElewski, Michael Negin, "*Robotics Engineering an Integrated Approach"*, Prentice Hall of India Pvt. Ltd., 1989
4. Carl D. Crane and Joseph Duffy, "*Kinematic Analysis of Robot manipulation"*, Cambridge University press, 1998.
5. Yoram Koren, "*Robotics",* McGraw Hill, 1992.
6. K. C. Jain and Agarwal L. N. *"Robotics Principles and Practice",* Khanna Publishers, 1997.
7. Yu Kozihev, *"Industrial Robots Handbook",* MIR Publications, 1997.

Course Name- Mechatronics
Course Code- ME 665

UNIT I: Mechatronics and Signal conditioning: Introduction, Systems, Measurement Systems, Control Systems, Microprocessor - based controllers, Response of systems. The Mechatronics Approach, Digital signals, Multiplexers, Data acquisition systems, Digital signal processing, Pulse modulation, OPAM, measurement systems, Testing and calibration.

UNIT II : Pneumatic and hydraulic actuation system: Actuation systems, Pneumatic and hydraulic systems, Directional control valves, Pressure control valves, Cylinders, Process control valves, rotary actuators.

UNIT III: Mechanical Actuation Systems: Mechanical Systems, Types of Motions, Kinematic chains, Cams, Gear Trains, Ratchet and pawl, belt and chain drives, Bearings, Mechanical aspects of motor selection

UNIT IV: System models: Mathematical models, Mechanical system building blocks, electrical system building blocks, fluid system building blocks, thermal system building blocks , Engineering systems, Rotational-translational systems, Electromechanical systems, Hydraulic-mechanical systems.

UNIT V : System Transfer function: First order systems, Second order systems, Transfer functions Block diagrams, signal flow graphs Systems with feedback loops. Elect of pole location on transient response, MATLAB, SIMULINK applications .

UNIT VI Controllers: Micro processor systems, Micro controller systems and applications, Programmable Logic controllers, Basic structure, input/output processing, selection of a PLC Programming and applications.

Text Books:-

1. W.Bolton,*Mechatronics, Electronic Control Systems in Mechanical and Electrical Engineering*,Pearson Education, Ltd.

References:

1. Anthony Esposito,*Fluid Power with Applications*, Pearson Education 2000.

2. Johnson, James L, *Introduction to Fluid Power*, Delmar Publishers, 2003.

3. I J Nagrath, M Gopal, *Systems Modelling and Anlysis*, Tata McGraw Hill,New Delhi, 3rd Edition 2008.

4. K Ogata, *Modern Control Engineering*, 5th Edition,Prentice Hall, 2010.

5. M W Spong and M Vidyasagar, *Robot Dynamics and Control*, John Wiley & sons, NY, USA,2004.

Course Name- Introduction to Mechanisms **(NonMechanical)**

Course Code- ME 639

UNIT I Physical Principles: Force and Torque, Motion, Newton's Law of Motion, Momentum and Conservation of Momentum, Work, Power and Energy

UNIT II Simple Machines: The Inclined Plane, Screw Jack, Gears, Belts and Pulleys, Lever, Wedge, Efficiency of Machines

UNIT III Machines and Mechanisms: Planar and Spatial Mechanisms, Kinematics and Dynamics of Mechanisms, Links, Frames and Kinematic Chains, Skeleton Outline, Pairs, Higher Pairs, Lower Pairs and Linkages, Kinematic Analysis and Synthesis

UNIT IV Kinematics: Basic Kinematics of Constrained Rigid Bodies, Degrees of Freedom of a Rigid Body, Kinematic Constraints, Constrained Rigid Bodies, Degrees of Freedom of Planar Mechanisms, Finite Transformation, Transformation Matrix Between Rigid Bodies

UNIT V Planar Linkages: Introduction, Four Link Mechanisms, Cams - Gears: Gear Classification, Gear-Tooth Action, Involute Curve, Terminology for Spur Gears, Condition for Correct Meshing, Ordinary Gear Trains, Planetary gear trains

UNIT VI Various Mechanisms: Ratchet Mechanisms, Overrunning Clutch, Intermittent Gearing, The Geneva Wheel, The Universal Joint.

Practice :

1. Msc adams tutorials
2. Mechanisms Design in Solidworks
3. Analysis Simulations etc.

Reference/Text Books:

1. P. Beer& Johnson, *Vector Mechanics for Engineers and Scientists Statics and Dynamics*, Tata McGraw Hill, New Delhi, 2001.
2. Shingley.J.E. *Theory of Machines and Mechanisms*, 2nd Edition, McGraw Hills Inc, 1995.
3. J.E. Shigley, *Mechanical Engineering Design*, McGraw Hill International, 2001.
4. Joseph Heitner, *Automotive Mechanics*, Affiliated East West Pvt. Ltd, 2nd, 2013.

Course Name: Introduction to Electronics Systems(Non Electronics)
Course Code: EE649

UNIT-I: REVIEW SEMICONDUCTOR DEVICES

Two terminal devices, three terminal devices: BJT, JFET, MOSFET, four terminal devices: SCR, DIAC, TRIAC, photo devices: photo diode, LED, LCD.

Half wave rectifier, full wave rectifiers, filter circuits, regulated power supplies: introduction, characteristics, stabilization.

UNIT-II: AMPLIFIERS AND OSCILLATORS

Transistor as an amplifier, single stage amplifier, multistage amplifier, Class A, B, and C amplifiers. Introduction to operational amplifier, specification and characteristics, application: constant gain, voltage summing, voltage buffer, instrumentation circuits, active filters. Oscillators.

UNIT-III: INTRODUCTION TO COMPUTING

Number system and code conversion, logic gates, Boolean algebra, combinational circuit design, sequential circuit, flip flops, counters, shift registers, decoder, encoder, MUX, DEMUX, memories, I/O, programmable logic devices, microprocessors and microcontrollers.

UNIT-IV: MEASUREMENTS AND INSTRUMENTS

Introduction, Analog to Digital converters and Digital to Analog converters, digital multimeter, frequency counters.

Sensors: temperature sensor, force and pressure sensor, magnetic field sensor, optical sensor, microwave sensor, acoustic sensor, and image sensor.

UNIT-V: INTRODUCTION TO OTHER ELECTRONIC SYSTEMS

Analog communication system, digital communication system, wireless communication system, embedded system, real time system, VLSI, RF.

Reference Books:

1. Robert L Boylestad, Electronic Devices & Circuit Theory, Pearson Education, 11th Edition, 2013.

2. Thomas L. Floyd, Digital Fundamentals, Pearson Education, 11th Edition, 2015.
3. Thomas L. Floyd, Electronic Devices, Pearson Education, 9th Edition, 2012.
4. Jacob Fraden, Handbook of Modern Sensors, Springer, 4th Edition, 2010.

Course Name- Artificial Intelligence and Expert Systems

Course Code- CE 696

UNIT I : Introduction to AI, Knowledge-based Intelligent Systems, Rule based Expert Systems – Search Methods - Uncertainty Management in rule-based expert systems: Introduction to Uncertainty, Basic Probability Theory, Bayesian reasoning, Certainty Factors

UNIT II: Fuzzy Expert Systems: Introduction to Fuzzy thinking, Linguistics variables and Hedges, Fuzzy Rules, Fuzzy Inference, Defuzzification

UNIT III: Learning: Overview of different forms of learning, Learning Decision Trees, Neural Networks, Natural Language Processing

UNIT IV : Artificial Neural Networks: Basics of Neuron, Perceptron, Multi-layer neural network, Hop-field network, Self- Organizing Neural Networks

UNIT V: Evolutionary Computation: Genetic Algorithms, Evolution Strategies - Hybrid Intelligent Systems: Neuro-Fuzzy, ANFIS; Probabilities, Bayesian Networks

UNIT VI : Applications of AI in Robotics: Subsumption Robots, Subsumption Architecture, Strengths and Weaknesses of the Architecture. Sensors, vision camera etc. for perception and obstacle avoidance

Text/References:

1. Stuart Russell & Peter Norvig, *Artificial Intelligence: A Modern Approach*, Prentice-Hall, 3rd Edition, 2009.
2. E. Rich and K. Knight, *Artificial Intelligence*, 2nd ed., McGraw-Hill, New York, 1991.
3. Morgan Kaufmann, San Mateo, M. Ginsberg, *Essentials of Artificial Intelligence*, Ca. 1993.
4. D. Poole and A. Mackworth, *Artificial Intelligence: Foundations of Computational Agents*, Cambridge University Press, Cambridge, UK, 2010.
5. P. H. Winston, *Artificial Intelligence*, 3rd ed., Addison-Wesley, Reading, Mass., 1992.
6. Brooks, Rodney, *Cambrian Intelligence: The Early History of the New AI.* Cambridge, Massachusetts: The MIT Press. pp. 8–12; 15–16. ISBN 0-262-02468-3, 1999

Course Name- Robotic Sensors, Actuators and Drives

Course Code-ME 666

Unit I: Introduction to sensors, classification, Commonly detectable phenomenon in nature, transducers -common conversion methods, Principle of operation of sensors, Classification, static characteristics, selection criteria, signals conditioning, calibration.

Unit II: Working Principle of operation of industrial sensors, displacement sensors, synchros and resolvers, Temperature measurement sensors, pressure measurement sensors, Proximity sensors, Ultrasonic, magnetic, light sensors, Flow measurement sensors, speed measurement, Tactile sensors, shape memory alloy materials, smart sensing, applications.

Unit III: Principle of operation of actuators, fundamental laws, classification, speed torque characteristics of DC motors, induction motors, synchronous motors,Speed control methods and applications.

Unit VI: Servo motors, switched reluctance motors, BLDC motors, stepper motor types, universal motor, torque motor, construction, torque- speed characteristics, applications, merits and demerits.

Unit V: Power flow control switching, power electronic devices, power MOSFET, power BJT, SCR, V- I, turn on, turn off characteristics, triggering methods, PWM methods. Induction motor drives, VSI, CSI, cyclo-converters, static Kramer drive, static Scherbius drive, synchronous motor drives, stepper motor drives, BLDC drivers, PMAC drivers, switched reluctance motors drives.

Unit VI: Components of electric drives, factors affecting choice of drives, fundamental torque equation, speed-torque conventions, steady state stability, multi-quadrant operation of electric drives, load torque components, load equalization, determination of motor power rating, motor duty cycles, electric braking,modes of operation, speed control and drive classification, closed loop control, current limit control, speed control, position control, torque control, PLL control, multi-motor drive control, digital control. DC motor control, speed control, position control, proportional control, PID controllers.

Text books:

1. Gopal K. Dubbey*,"Fundamentals of Electric Drives", (2e)*, Narosa Publishers, 2001.
2. M. H. Rashid, "Power electronics, circuits,devices and applications",Pearson publishers,2014.
3. J. B. Gupta, " Theory & performance of Electric Machines", S K Kataria & Sons,2013.

References:

1. A.K.Sawhney ,"*A course in Electrical and Electronic measurements and instrumentation*" DhanpatRai&Co.Publication.
2. W. Shepherd, and L. N. Hully, *"Power Electronics and Motor control", (2e)*, Cambridge University, 1995.
3. R. Krishnan, *"Electric Motor Drives Modeling, Analysis, and Control", (2e)*, Prentice Hall, 2001

Course Name- Mathematics for Engineer

Course Code-AM 607

Unit I : Linear Algebra: General (real) vector spaces, Subspaces, Linear independence, Dimension, Norms, Orthogonal bases and Gram-Schmidt orthogonalization- Principles of floating point computations and rounding errors

Unit II : Systems of Linear Equations: factorization methods, pivoting and scaling, residual error correction method - Iterative methods: Jacobi, Gauss-Seidel methods with convergence analysis, Conjugate gradient methods

Unit III : Nonlinear systems: Newton and Newton like methods - Interpolation: review of Lagrange interpolation techniques, Newton interpolation, piecewise linear, cubic splines and Bezier curves, error estimates - Approximation: uniform approximation by polynomials, data fitting and least squares approximation

Unit IV : Numerical differentiation and integration: Differentiation and integration by interpolation, adaptive quadratures and Gaussian quadrature - Initial Value Problems for Ordinary Differential Equations: Euler, Modified Euler, Runge -Kutta methods, multi - step methods, predictor and corrector methods, stability and convergence analysis

Unit V : Two Point Boundary Value Problems: finite difference methods with convergence results - Solution of PDE: Parabolic, Hyperbolic and Elliptic Equations using finite difference method.

Text/References:

1. Gilbert Strang, *Linear Algebra and its Applications*, Academic Press, 4th Ed., 2008.
2. Thomas S Shores, *Applied Linear Algebra and Matrix Analysis*, Springer, 2007.
3. Richard L. Burden, J. Douglas Faires, Brooks/Cole, *Numerical Analysis*, 9th Ed., 2010.
4. Kendall E. Atkinson, *An Introduction to Numerical Analysis*, John Wiley & Sons, 2nd Ed., 2008.
5. Samuel D Conte and Carl de Boor, *Elementary Numerical Analysis - An Algorithm Approach*, McGraw Hill, 3rd Ed, 2008.
6. M. K. Jain, S.R.K. Iyengar, R.K. Jain, *Numerical Methods for Scientific and Engineering Computation*, New Age International Ltd, 6th Ed., 2012.
7. K. W. Morton, D. F. Mayers, *Numerical Solutions of Partial Differential Equations: An Introduction*, Cambridge University Press, 2nd Ed., 2005.
8. Gene H. Golub, J. M. Ortega, *Scientific Computing and Differential Equations: An Introduction to Numerical Methods*, Academic Press, 2nd Ed. 1992.
9. G. Pozrikidis, *Numerical Computation in Science and Engineering*, Oxford University Press, 2nd Ed., 2008.

Course Name- Robot Kinematics and Dynamics

Course Code- ME 667

Unit I: Introduction, position and orientation of objects, objects coordinate frame Rotation matrix, Euler angles Roll, pitch and yaw angles coordinate Transformations, Joint variables and position of end effectors

Unit II : Dot and cross products, coordinate frames, Rotations, Homogeneous coordinates, link coordinates D-H Representation, The ARM equation. Direct kinematic analysis for Four axis, SCARA Robot and six axis Articulated Robots

Unit III : The inverse kinematics problem, General properties of solutions. Tool configuration, Inverse kinematics of four axis SCARA robot and six axis Articulated robot

Unit IV : Workspace Analysis, work envelope of a Four axis SCARA robot and five axis articulated robot workspace fixtures, the pick and place operations, continuous path motion, Interpolated motion, straight line motion

Unit V : Introduction, lagrange's equation kinetic and potential energy. Link inertia Tensor, link Jacobian Manipulator inertia tensor. Gravity, Generalized forces, Lagrange-Euler Dynamic model, Dynamic model of a Two-axis planar robot Newton Euler formulation, Lagrange - Euler formulation, problems.

Practice:

1. Robot Analyzer Platform Experiments
2. Simulation Software for Robotics
3. Case studies

Text/References:

1. Robert J. Schilling, *Fundamentals of Robotics Analysis and Control*, Prentice Hall of India Pvt. Ltd., 2000
2. Richard D. Klafter, Thomas. A, Chmielewski, Michael Negin, *Robotics Engineering an Integrated Approach*, Prentice Hall of India Pvt. Ltd., 1989
3. P.A. Janaki Raman, *Robotics and Image Processing an Introduction*, Tata Mc Graw Hill Publishing company Ltd., 1995
4. Francis N-Nagy AndrasSiegler, *Engineering foundation of Robotics*, Prentice Hall Inc., 1987
5. Bernard Hodges, *Industrial Robotics*, Jaico Publishing house, 2nd Edition, 1993.
6. Tsuneo Yohikwa, *Foundations of Robotics Analysis and Control*, Prentice Hall of India Pvt. Ltd., 2001.
7. John J. Craig, *Introduction to Robotics Mechanics and Control*, Second Edition, Addison Wesly Longman Inc. International Student edition, 1999

8. Bijay K. Ghosh, Ning Xi, T.J. Tarn, *Control in Robtics and Automation Sensor - Based integration*, Academic Press, 1999
9. M.P. Groover , Mitchel Weiss, *"Industrial Robotics: Technology, Programming and Applications"(2e),* McGraw Hill ,2012

Course Name- Machine Vision and Image Processing

Course Code-ME 668

Unit I: Architecture of Robotic vision system, Image acquisition, representation, processing Data Acquisition, Conversion, Transmission and Processing: Inertial sensors, Laser Scanners 2D and 3D, Robot Vision, 3D cameras, filters for removal of noise and, INS, gyroscopes,2D,3D Scanner platforms.

Unit II: Image acquisition and analysis, Vision and image sensors, digitization, preprocessing, vision system components, basic optics, basic radiometry, image formats, image noise, image representation, color space, conversion of color spaces.

Unit III : Image enhancement, operations on images, noise removal, segmentation, thresholding, edge detection algorithms, morphological operations, image analysis coding and representation of regions, dimensional analysis, feature extraction Fourier transformations, spatial domain techniques, discrete cosine transform to images, image scaling, standard video formats.

Unit IV: 3D vision: Perspective projection geometry, pinhole camera model, lens distortion, affine and metric geometry, 2d and 3d geometrical transformations, intrinsic and extrinsic camera parameters, calibration methods, stereovision, epipolar geometry, triangulation, rotational matrix, fundamental matrix, stereo correspondence algorithms – feature based and correlation based, 3d reconstruction.

Unit V: Motion estimation and tracking: Optical flow estimation, the concept of sensor fusion - Kalman filter, Localization and Mapping techniques, object tracking with Kalman filtering, feature extraction & object recognition

Unit VI: Case studies/application: Industrial application of vision controlled Robotics systems.Face recognition, vehicle tracking, industrial robot guidance, demonstration of applications using computer vision toolbox and image processing toolbox.

References:

1. Milan Sonka, Vaclav Hlavac, Roger Boyle, *Image Processing, Analysis and Machine Vision", (2/e)*, 1998.
2. Rafael C. Gonzalez, Richard E. Woods, *Digital Image Processing, (2/e)*, Pearson education, 2003.
3. Boguslaw Cyganek& J. Paul Siebert, *An Introduction to 3D Computer Vision Techniques and Algorithms*, Wiley, 2009.

4. E.R. Davies, Royal Holloway, *Machine Vision: Theory, Algorithms and Practicalities, (3/e)*, University of London, December 2004.

5. R. Jain, R. Kasturi, B. G. Schunck, *Machine Vision*, McGraw-Hill, New York, 1995.

6. P.A. Janaki Raman, Robotics and Image Processing an Introduction, Tata Mc Graw Hill Publishing company Ltd., 1995.

Course Name- SoC AND EMBEDDED SYSTEM

Course Code- EE620

Unit-I: Introduction: Definition and Classification, Overview of Processors and hardware units in an embedded system, Software embedded into the system, Exemplary Embedded Systems, Embedded Systems on a Chip (SoC) and the use of VLSI designed circuits.

Unit-Ii: Devices And Buses For Devices Network: I/O Devices, Device I/O Types and Examples, Synchronous, I/o synchronous and Asynchronous Communications from Serial Devices, Examples of Internal Serial-Communication Devices, UART, Parallel Port Devices, Sophisticated interfacing features in Devices/Ports, Timer and Counting Devices, I2C, USB, CAN and advanced I/O Serial high speed buses, ISA, PCI, PCI-X and advanced buses.

Unit-Iii: Embedded Computing: Embedded processors, ARM processor, Architecture, Instruction sets and programming Case Studies, Parallel Computing, CUDA Language for radar Application.

Unit-Iv: Advanced Embedded Computing: Programmable System on Chip, Cypress PSoC Technology. Advance DSP Processors. FPGA Technology towards Embedded system aspects- Pico blaze and micro blaze processors- Embedded RAM- Embedded multiplier FPGA coding using VHDL/ Verilog Associated Labs: Assignments using Microcontroller kits, FPGA kits.

Text Books:

1. ARM System-on-Chip Architecture (2nd Edition) Steve Furber.
2. Advanced FPGA Design: Architecture, Implementation, and Optimization, Steve Kilts, IEEE press Wiley
   2007.
3. An Embedded software primer David E Simon,Pearson Education Twelfth India reprint,2005
4. Desiging Embedded systems with PIC microcontrollers Principles and Applications ,Tim Wilmshurst,
   Elsevier (Newnes), first edition 2007

Reference Books:

1. http://www.xilinx.com/publications/xcellonline: Xcell Journal.
2. DSP Architecture, Programming and Application- B Venkataramani, M Bhaskar.
3. Wayne Wolf, Computers as Components; Principles of Embedded Computing System Design – Harcourt India.

LIST OF EXPERIMENTS:

Sr. No	Experiment
1	Simulation of ALP using 8086 Emulator
2	FPGA programming using VHDL.
3	Radar signal generation using FPGA.
4	Creating a custom IP core using the IP Integrator in Vivado IDE
5	Recording and play back of audio signal using Zedboard DMA
6	Peripheral Module Interface using soft core processor Microblaze
7	PWM Applications using PSoC
8	Introduction to CUDA programming and Tesla Processors

Course Name- Robotic Path Planning and Control

Course Code- ME 663

Unit I Path Planning: Processes in Robot Control: Path planning – Trajectory Generation – Robot Control, Bug Algorithms: Bug1, Bug2, Tangent Bug algorithms, Planning motion in C-space, Potential field approach, Visibility Graph method for polygonal obstacles, Gradient method and dynamic window for mobile robots, Cell decomposition method, Approximate cell decomposition method, A* and D* algorithms, Probabilistic roadmap planner, Rapidly exploring random trees.

Unit II Trajectory generation: Cubic polynomial – path with via points – velocities at via points, Higher order polynomials, Linear function with parabolic blends – path with via points, pseudo via points to create a through point, Cartesian space schemes, Cartesian straightline motion

Unit III Linear Robot Control: Independent joint control approximation, 2nd order linear systems, Control law partitioning, Trajectory following controller, Disturbance rejection, PID control, Modeling & control of single joint, Unmodeled flexibilities, Resonant frequencies, Architecture of an industrial robot controller.

Unit IV Nonlinear control of manipulators: Example nonlinear systems, Coulomb friction, Single link manipulator, Multi-input Multi-output control systems, Model based manipulator control scheme, Feedforward nonlinear control, Effects of payload and disturbances, Imperfect knowledge of parameters of manipulator dynamics, Industrial robot control system, Approximations of decoupling control, Lyapunov stability analysis: Nonlinear spring damper, Manipulator, Cartesian based control system, Jacobians in the force domain, Cartesian force based control, Cartesian decoupling scheme, Adaptive control.

Unit V Force control: Framework for control in partially constrained task, Artificial constraints, Hybrid position/force control: Force control of a mass spring, Hybrid position/force control of a cartesian manipulator, Hybrid controller of a 3-dof Cartesian arm, Hybrid position/force controller for a general manipulator, Variable stiffness, Passive compliance through remote centre compliance device, compliance through softening position gains.

References and Text Books-

1. John J. Craig, *Introduction to Robotics Mechanics and Control*, 3rd Edition, Pearson, 2008.
2. K. Ogata, *Modern Control Engineering*, 5th Edition, Prentice Hall, 2010
3. B. Friedland, *Control System Design-An Introduction to State Space Methods*, McGraw-Hill, Singapore, 1987
4. J.J.E Slotine and W. Li, *Aplied Nonlinear Control*, Prentice-Hall, NJ, 1991
5. M. W. Spong and M. Vidyasagar, *Robot Dynamics and Control*, John Wiley & Sons, NY, USA, 2004
6. Howie M Choset, Seth Hutchinson, Kevin M Lynch, George Kantor, Wolfram Burgard, Lydia E Kavraki, Sebastian Thrun *Principles of Robot Motion: Theory, Algorithms, and Implementation*, 2005

LIST OF ELECTIVES

Sr no	Course code	Course Name
1	ME 614	Unmanned ground vehicles
2	ME 628	Design of Hydraulic and Pneumatic System
3	ME 629	Industrial Automation
4	ME 631	Product design and development
5	ME 634	Flexible Manufacturing systems
6	ME 635	CAD/CAM
7	ME 638	Field and service Robots
8	ME 642	Automatic Control System
9	ME 653	Introduction to Mobile Robotics
10	ME 655	Performance testing and Instrumentation
11	ME 669	Humaniod
12		Elective from other Dept.

ME 614 Unmanned Ground vehicles

Introduction to UGV, Classification of UGV, History /World Scan, Major Technologies Sub system of UGV, Mobile UGV Kinematics, Locomotion, Drive by wire technology, Planning & Navigation, Obstacle detection & warning system, Power supply system, Perception System, Payloads, Vehicle Platforms, Automatic Transmission, Controllers Tele operation, Sensors & Actuators, Allied Technology, Applications.

Text/References:

1. Autonomous Mobile Robots by Roland Siegwart, Illah R. Nour bakhsh, Davide Scaramuzza (Printice Hall)

2. Autonomous robots: From biological inspiration to implementation and control, By Bekey, G.A.

3. Intelligent unmanned ground vehicles- autonomous navigation research at carnegie mellon,By Hebert, M.H. Thorpe, C Stentz, A.

4. Robot technology fundamentals, by Keramas, J.G.

5. Principles of robot motion Theory algorithms and implementations by Choset, H. Lynch, K.M. Hutchinson, S. Kantor, G. Burgard, W. Kavraki, L.E. Thrun, S.

ME 628 Design of Hydraulic and Pneumatic Systems

Unit I: Hydraulic System & Components-Sources of Hydraulic Power: Pumping theory – Pump classification – Gear pump, Vane Pump, piston pump, construction and working of pumps – pump performance – Variable displacement pumps. Fluid Power Actuators: Linear hydraulic actuators – Types of hydraulic cylinders – Single acting, Double acting special cylinders like tanden, Rodless, Telescopic, Cushioning mechanism, Construction of double acting cylinder, Rotary actuators – Fluid motors, Gear, Vane and Piston motors

Unit II: Design of Hydraulic Circuits-Construction of Control Components : Director control valve – 3/2 way valve – 4/2 way valve – Shuttle valve – check valve – pressure control valve – pressure reducing valve, sequence valve, Flow control valve – Fixed and adjustable, electrical control solenoid valves, Relays, ladder diagram. Accumulators and Intensifiers: Types of 89 accumulators – Accumulators circuits, sizing of accumulators, intensifier – Applications of Intensifier – Intensifier circuit.

Unit III: Pneumatic Systems and Components-Pneumatic Components: Properties of air – Compressors – Filter, Regulator, and Lubricator Unit – Air control valves, Quick exhaust valves, and pneumatic actuators. Fluid Power Circuit Design, Speed control circuits, synchronizing circuit, Penumo hydraulic circuit, Sequential circuit design for simple applications using cascade method.

Unit IV: Design of Pneumatic Circuits-Servo systems – Hydro Mechanical servo systems, Electro hydraulic servo systems and proportional valves. Fluidics – Introduction to fluidic devices, simple circuits, Introduction to Electro Hydraulic Pneumatic logic circuits, ladder diagrams, PLC applications in fluid power control. Fluid power circuits; failure and troubleshooting.

Text Books:

1. Anthony Esposito, Fluid Power with Applications, Pearson Education 2000.

2. Majumdar S.R., Oil Hydraulics, Tata McGraw-Hill, 2000.

3. Johnson, James L., Introduction to Fluid Power, Delmar Publishers, 2003 Reference Books:

4. Majumdar S.R., Pneumatic systems – Principles and maintenance, Tata McGraw Hill, 1995

5. Harry L. Stevart D.B, Practical guide to fluid power, Taraoeala sons and Port Ltd. Broadey, 1976.

6. Michael J, Prinches and Ashby J. G, Power Hydraulics, Prentice Hall, 1989.

7. Dudelyt, A. Pease and John T. Pippenger, Basic Fluid Power, Prentice Hall, 1987.

ME 629 Industrial Automation

Unit I: Production operations and Automation strategies - Types of production, Functions in manufacturing, Plant Layout, Production concepts and Mathematical models, Automation strategies. Production Economics.

Unit II: Cost in manufacturing, break even analysis, Unit cost of production, Cost of manufacturing lead time and work-in-progress - Detroit - Type automation - Automated flow line, workpart transport, Transfer mechanism, Buffer storage, Control functions, Automation for machining operations, Design and fabrication consideration. Analysis of Automated Flow lines. General terminology and analysis.

Unit III: Analysis of transfer lines without storage, partial automation, Automated flow lines, with storage buffer, simulation of automation flow lines - Numerical Control, Types of NC Systems, Machine tool applications, other applications of NC Systems, Components of NC System, Introduction to NC part programming, Types of part programming, Direct Numerical Control, Computer Numerical Control, Adaptive Control Machining - The assembly process, assembly systems, manual assembly lines.

Unit IV: The line balancing problem, Methods of line balancing, Computerised line balancing method, flexible manual assembly lines. Design for automated assembly, types of automated assembly system, parts feeding devices, Analysis of single station and multistation assembly machine - Automated materials handling: Types of material handling equipment, analysis for material handling systems, design of the system, conveyor system, automated guided vehicle systems. Automated storage systems: Automated storage / Retrieval systems, Carousel storage systems, work-in-process storage, interfacing handling and storage with manufacturing.

References/Texts

1. Mikell.P. Groover, *Automation, Production Systems and Computer Integrated Manufacturing*, Prentice Hall of India Pvt. Ltd., Thirteenth Indian Reprint, 2001.
2. P.N. Rao, 'CAD/CAM Principles and Applications' Tata McGraw Hill Publishing Company Ltd., 2002

ME 631 Product Design and Development

Unit I:Introduction- Significance of product design, product design and development process, sequential engineering design method, the challenges of product development,

Unit II: Product Planning and Project Selection- Identifying opportunities, evaluate and prioritize projects, allocation of resources Identifying Customer Needs: Interpret raw data in

terms of customers need, organize needs in hierarchy and establish the relative importance of needs.

Unit III: Product Specifications- Establish target specifications, setting final specifications, Concept Generation: Activities of concept generation, clarifying problem, search both internally and externally, explore the output.

Unit IV: Industrial Design-Assessing need for industrial design, industrial design process, management, assessing quality of industrial design, Concept Selection:Overview, concept screening and concept scoring, methods of selection.

Unit V: Theory of inventive problem solving (TRIZ)-Fundamentals, methods and techniques,

General Theory of Innovation and TRIZ, Value engineering Applications in Product development and design, Model-based technology for generating innovative ideas

Unit VI: Concept Testing- Elements of testing: qualitative and quantitative methods including survey, measurement of customers' response. Intellectual Property- Elements and outline, patenting procedures, claim procedure, Design for Environment-Impact, regulations from government, ISO system.

Text books and references:

1. Ulrich K. T, and Eppinger S.D, *Product Design and Development*, Tata McGraw-Hill Education, 2003
2. Otto K, and Wood K, *Product Design*, Pearson, 2001.
3. By Semyon D. Savransky, *Engineering of creativity: Introduction to TRIZ methodology of inventive Problem Solving*, CRC Press, Aug 29, 2000.
4. Michael A. Orloff, *Inventive thinking through TRIZ: a practical guide*, Springer Verlag, 2003.
5. John Terninko, AllaZusman, *Systematic innovation: an introduction to TRIZ; (theory of inventive Problem Solving),* CRC Press., Apr 15, 1998.

ME634 Flexible Manufacturing Systems

Unit I: Definition of an FMS-need for FMS, types and configuration, types of flexibilities and performance measures. Economic justification of FMS. Development and implementation of FMS- planning phases, integration, system configuration, FMS layouts,

simulation

Unit II: Functions, types, analysis of material handling systems, primary and secondary material handling systems-conveyors, Automated Guided Vehicles-working principle, types, traffic control of AGVs.Roleof robots in material handling.

Unit III : Automated storage systems- storage system performance - AS/RS-carousel storage system, WIP storage systems, interfacing handling and storage with manufacturing - Planning, scheduling and computer control of FMS, Hierarchy of computer control, supervisory computer.

Unit IV :DNC system- communication between DNC computer and machine control unit, features of DNC systems - System issues, types of software - specification and selection-trends-application of simulation and its software, Manufacturing Data systems- planning FMS data base.

Unit V : Modelling of FMS- analytical, heuristics, queuing, simulation and petrinets modeling techniques - Scheduling of operations on a single machine- two machine flow shop scheduling, two machine job shop scheduling - three machine flow shop scheduling-scheduling 'n' operations on 'n' machines, knowledge based scheduling, scheduling rules, tool management of FMS, material handling system schedule.

References/ Texts:

1. N K Jha, *Handbook of Flexible Manufacturing Systems*, Academic Press, 2012.
2. A. Raouf, M. Ben-Daya, *Flexible Manufacturing Systems: Recent Developments*, Elsevier, 09-Feb-1995.

ME 635 CAD/CAM

Unit I : Criteria for selection of CAD workstations, Shigle Design Process, Design criteria, Geometric modeling, entities, 2D & 3D Primitives. 2D & 3D Geometric Transformations: Translation, Scaling, Rotation, Reflection and Shearing, concatenation.

Unit II: Graphics standards: GKS IGES, PDES. Wire frame modeling: Curves: Curve representation. Analytic curves – lines, Circles, Ellipse, Conis. Synthetic curves – Cubic, Bezier, B-Spline, NURBS - Surface entities, Surface Representation.

Unit III: Analytic Surface – Plane Surface, Ruled Surface, Surface of Revolution, Tabulated Cyliner. Synthetic Surface-Cubic, Bezier, Bspline, Coons - Graph Based Model, Boolean

Models, Instances, Cell Decomposition & Spatial – Occupancy Enumeration, Boundary Representation (B-rep) & Constructive Solid Geometry (CSG)

Unit IV: Feature Based Modeling, Assembling Modeling, Behavioural Modeling, Conceptual Design & Top Down Design.

Unit V: Capabilities of Modeling & Analysis Packages such as solid works, Unigraphics, Ansys, Hypermesh. Computer Aided Design of mechanical parts and Interference Detection by Motion analysis.

Text/Reference:

1. M Groover and E. Zimmers, CAD/CAM: *Computer-Aided Design and Manufacturing*, Pearson Education, 1983.
2. A J Medland, *CAD/CAM in Practice*, Springer science and media, 2012

ME 638 Field and service Robots

Unit I Introduction to Field and service robots: History of service robotics – Present status and future trends – Need for service robots – applications examples and Specifications of service and field Robots. Non conventional Industrial robots. Classification, applications, sensing and perception, social and ethical implications of robotics

Unit II Autonomous Mobile robots: Kinematics, locomotion, perception, motion planning and control, localization and mapping. Road map path planning, intelligent unmanned vehicles. Wheeled and legged, Legged locomotion and balance, Arm movement, Gaze and auditory orientation control, Facial expression, Hands and manipulation, Sound and speech generation, Motion capture/Learning from demonstration, Human activity recognition using vision, touch, sound, Vision, Tactile Sensing, Models of emotion and motivation. Performance, Interaction, Safety and robustness

Unit III Field Robots: Collision Avoidance-Robots for agriculture, mining, exploration, underwater, civilian and military applications, nuclear applications, Space applications. Industrial applications like cleaning robots, wall painting robots, wall plastering robots, vehicle equipment and building robots etc Load carrying robots. IDE detection and diffusion robots

Unit IV Underwater robots: Kinematics and dynamics, modeling and simulation, navigation, guidance and control. Marine data collection (Temperature, other environment parameters)

Unit V Aerial robots: Basics of aerial robots, sensors and actuators, modelling and control of small Unmanned Aerial vehicles, guidance and navigation of small range aerial robots, Autonomous indoor flight control Air defence robots.

Text Books:

1. Roland Siegwart, Illah Reza Nourbakhsh, DavideScaramuzza, *Introduction to Autonomous Mobile Robots*, Bradford Company Scituate, USA, 2004
2. RiadhSiaer, *The future of Humanoid Robots- Research and applications*, Intech Publications, 20

Reference books:

1. Richard D Klafter, Thomas A Chmielewski, Michael Negin, "*Robotics Engineering – An Integrated Approach*", Eastern Economy Edition, Prentice Hall of India P Ltd., 2006.
2. Kelly, Alonzo; Iagnemma, Karl; Howard, Andrew, *Field and Service Robotics*, Springer, 2011.

ME 642 Automatic Control Systems

Unit I: Basic concepts of Automatic Control- Transfer Functions-Modeling of systemsMechanical, Electrical, hydraulic system block diagram, signal flow graphs, closed and open loop systems. Feedback and Feed forward control system.

Unit II: Static and Dynamic Characteristics of Control Systems- Transient Response and Steady state error analysis for First and second order systems. Frequency response. Experimental determination of transfer function. Stability Analysis. Root Locus Analysis. Nyquist Criteria.

Unit III: Control Actions and Control System Components- Discrete action, Proportional, Integral and Differential Control Action, Composite action. Characteristics, working and limitations of different types of Comparators and actuators, amplifiers, Servo motors and Control valves.

Unit IV: Control System Implementations- Pneumatic Systems, Hydraulic Systems, Electrical Systems, Microprocessor Based Systems, Programmable Logic Controllers, Micro Controllers and Network Based Distributed Control Systems,

Unit V: Case Studies.

Texts Books:

1. Measurement System, Application & Design, 4thEd, E O Doebelin, Mc Graw Hill, 2003.
2. Modern Control Engineering, 4th Ed, Katushiko Ogata, Pearson, UK, 2001.
3. Modern Control Engineering, 4th Ed, Katushiko Ogata, Pearson, UK, 2001.

ME 653 Introduction to Mobile Robotics

Linear Algebra, Robot Control Paradigms, Wheeled Locomotion, Proximity Sensors, Probabilistic Robotics, Probabilistic Motion Models, Probabilistic Sensor Models, Bayes Filter

- Discrete Filter, Particle Filter and MCL, Kalman Filter, Extended Kalman Filter, Grid Maps and Mapping With Known Poses, SLAM - Simultaneous Localization and Mapping, SLAM - Graph-based SLAM, Techniques for 3D Mapping, Iterative Closest Point Algorithm, Path and Motion Planning, Multi-Robot Exploration, Information Driven Exploration.

Text Books:

1. Roland Siegwart, Illah Reza Nourbakhsh and DavideScaramuzza, *Introduction to Autonomous Mobile Robots*, 2nd Edition, 2004.
2. Gregory Ducdeck, Michael Jenkin, *Computational Principles of Mobile Robotics*, Cambridge University Press, 2000.
3. H. R. Everet, *Sensors for Mobile Robots-Theory and Applications*, A.K. Peters, 1995.
4. Phillip McKerrow, *Introduction to Robotics*, Addison-Wesley, 1991.
5. Ronald Arkin, *Behavior Based Robotics*, MIT Press, 1998.

Course Name- Performance Testing and Instrumentation
Course Code- ME 655

Unit I: Performance testing of Machinery Sea Water Cooling, Lube Oil Fill/Transfer/Purification Systems, - Main Propulsion Lube Oil System, Starting Air Compressors and System, Ship Service and Control Air Equipment, Segregated Ballast System, Steam and Condensate System, Fuel Oil Service System, Fuel Oil Quick Closing Valves, High Temperature/Low Temperature Fresh Water Cooling Systems, Stern Tube Lube Oil System,

Unit II: Performance testing of Ship Service Generator Operational Tests, Emergency Diesel Generator , Batteries and Chargers, Lighting System Operation, Navigation and Signal Lights, Radio Communication Equipment, Ships Whistles, Tank Level Indicators, Auxiliary Boiler and Services, Fire and Foam System, Machinery Bilge and Oily Waste Transfer System

Unit III: Fundamental & Importance of Instrumentation, types of instruments, selection of instruments, performance of instruments, error in measurement, calibration & standard, Calibration of Instruments: Methods & analysis, Introduction to Transducer & types, Process Instrumentation, recording instruments, indicating & recording Instruments.

Unit IV: Measurements of temperature, pressure, relative humidity, moisture content & velocity & flow.

Reference/Text books:-

1. Experimental Methods, J.P. Holman McGraw Hill International, Auckland
2. Engineering Metrology, R KJain, Khanna Publishers, Delhi
3. Mechanical Measurements, Thomos G. Beckwith and I.ewis Back N. Adison Wesely Longman, Harlow
4. Industrial lnstrurnentation, John Wiley Eastern Ltd, New Delhi

Course Name- *Humanoid*

Course Code- *ME 669*

Unit I: Introduction to Humanoid Robotics ,state of the art, Kinamatics-Coordinate transforms, homogeneous transforms Characteristics of Rotational Motion. Velocity in Three Dimensional Space. Robot Data Structure and Programming, Kinematics of a Humanoid Robot .

Unit II: ZMP and Ground Reaction Forces, Measurement of ZMP Dynamics of Humanoid Robots Humanoid Robot Motion and Ground Reaction Force Momentum Angular Momentum Angular Momentum and Inertia Tensor of Rigid Body Calculation of ZMP from Robot's Motion.

Unit III: Biped Walking, Two Dimensional Walking Pattern Generation, Two Dimensional Inverted Pendulum, Planning a Simple Biped Gait, Extension to a Walk on Uneven Terrain, 3D Walking Pattern Generation, 3D Walking Pattern Generation, ZMP Based Walking Pattern Generation, Stabilizer-Principles of Stabilizing Control

Unit IV: Generation of Whole Body Motion Patterns, Generating Rough Whole Body Motion-Using Motion Capture, Using a Graphical User Interface, Using High Speed Multivariate Search Methods Converting Whole Body Motion Patterns to Dynamically Converting Whole Body Motion Patterns to Dynamically Stable Motion, Remote Operation of Humanoid Robots with Whole Body Motion Generation

Unit V: Dynamic Simulation, Dynamics of Rotating Rigid Body, Spatial Velocity Dynamics of Rigid Body Newton-Euler Equations Dynamics by Spatial Velocity Rigid Body Simulation Based on Spatial Velocity Dynamics of Link System

Text Books:-

1. Shuuji Kajita·Hirohisa Hirukawa Kensuke Harada·Kazuhito Yokoi, "*Introduction to Humanoid Robotics*", springer,2014.

References:

1. Ambarish Goswami Prahlad Vadakkepat, "*Humaniod Robotics*",Springer reference,2019