**National Education Policy (NEP) Compliant Curriculum Structure**

for

# B. Tech. (Robotics & Artificial Intelligence)

**(With effect from Academic Year 2024-25)**

# Department of Mechanical Engineering

**COEP Technological University (COEP Tech)**
A Unitary Public University of Government of Maharashtra
(Formerly College of Engineering Pune)
Wellesley Road, Shivajinagar,
Pune-411005, Maharashtra, India

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**Vision of the Department:**

**To be a leader amongst engineering institutions in India, offering value based world class education and constantly pursuing excellence**

**Mission of the Department:**

M1: To offer state-of-the-art undergraduate, postgraduate and doctoral programmes

M2: To develop employable and skilled undergraduate to accept the global and societal challenges, while imparting quality education at postgraduate and research level.

M3: To Foster the passion of life-long learning in all facets of employability.

**Program Educational Objectives (PEOs)**

**PEO1.** ***Core Competence*****:** Fundamental and technical knowledge with skills in Robotics & Artificial Intelligence area to enable and empower to solve problems of the modern industrial world.

**PEO2.** ***Depth (Research culture)*****:** Imbibing a scientific perspective to make a decision of Robotic systems and Artificial Intelligence using Mathematical, Engineering, Computational & Simulation tools.

**PEO3.** ***Professionalism:*** Make acquaint with technical, managerial, and human skills and familiarize with professional issues like ethics and morality, Intellectual property Rights, Constitution of India and Environmental responsibility.

**PEO4.** ***Learning Environment:*** Motivation for entrepreneurship and inculcating a spirit of continuous lifelong learning for a successful professional career.

**Program Outcomes**

**Program Outcomes of Engineering program as per norms (common to all UG/ PG Programme)**

**PO1. Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization for the solution of complex engineering problems.

**PO2. Problem analysis:** Identify, formulate, research literature, and analyses complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

**PO3. Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for public health and safety, and cultural, societal, and environmental considerations.

**PO4. Conduct investigations of complex problems:** The problems: • that cannot be solved by straightforward application of knowledge, theories and techniques applicable to the engineering discipline. • that may not have a unique solution. For example, a design problem can be solved in many ways and lead to multiple possible solutions. • that require consideration of appropriate constraints/requirements not explicitly given in the problem statement. (like: cost, power requirement, durability, product life, etc.). • which need to be defined (modeled) within appropriate mathematical frame work. • that often require use of modern computational concepts and tools.

**PO5. Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modelling to complex engineering activities, with an understanding of the limitations.

**PO6. 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.

**PO7. Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

**PO8. Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of engineering practice.

**PO9. Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

**PO10. Communication:** Communicate effectively on complex engineering activities with the engineering community and with the 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.

**PO11. 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 in a team, to manage projects and in multidisciplinary environments.

**PO12. 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 technological change.

**Program Specific Objectives (PSOs)**

**PSO1 Design and Development:** The ability to design and develop the products as per the need of the customers in the field of Mechanical and Allied Engineering Industries.

**PSO2 Engineering Analysis and optimization**: The ability to analyze and optimize the Mechanical systems/processes using various computational tools.

**PSO3 Society:** To strengthen Mechanical Engineering graduates who would value professional and ethical responsibilities while solving societal problems

## List of Abbreviations

| Abbreviation | Title |
|---|---|
| BS | Basic Science Course |
| ESC | Engineering Science Course |
| PCC | Programme Core Course (PCC) |
| PEC | Programme Elective Course (PEC) |
| OE/SE | Open/School Elective (OE/SE) other than particular program |
| MDM | Multidisciplinary Minor (MD M) |
| VSEC | Vocational and Skill Enhancement Course (VSEC) |
| HSMC | Humanities Social Science and Management |
| IKS | Indian Knowledge System (IKS) |
| VEC | Value Education Course (VEC) |
| RM | Research Methodology (RM) |
| -- | Internship |
| -- | Project |
| CEA | Community Engagement Activity (CEA)/Field Project |
| CCA | Co-curricular & Extracurricular Activities (CCA) |

# F.Y. B. Tech. Robotics & AI
## [Level 4.5, UG Certificate] Semester -I

| Sr. No. | Course Type | Course Code | Course Name | L | T | P | S | Cr | Evaluation Scheme (Weightages in %) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Theory | | | Laboratory | |
| | | | | | | | | | MSE | TA | ESE | ISE | ESE |
| 01 | BSC | MRAIBSC101 | Matrix Algebra, Calculus and Probability | 2 | 1 | 0 | 1 | 3 | 30 | 20 | 50 | -- | -- |
| 02 | BSC | MRAIBSC102 | Engineering Physics | 2 | 0 | 2 | 1 | 3 | 30 | 20 | 50 | CIE: 100 | |
| 03 | ESC | MRAIESC103 | Basic Electrical & Electronics Engineering | 2 | 0 | 2 | 1 | 3 | 30 | 20 | 50 | CIE: 100 | |
| 04 | ESC | MRAIESC104 | Engineering Drawing and Graphics | 1 | 0 | 4 | 1 | 3 | CIE: 100 | | | CIE: 100 | |
| 05 | ESC | MRAIESC105 | Engineering Mechanics | 3 | 0 | 2 | 1 | 4 | 30 | 20 | 50 | CIE: 100 | |
| 06 | AEC-I | MRAIAEC106 | Communication Skill | 1 | 0 | 2 | 0 | 2 | CIE: 100 | | | CIE: 100 | |
| 07 | CCA | | Liberal Learning Course-I | 0 | 0 | 2 | 2 | 1 | -- | -- | -- | CIE: 100 | |
| 08 | VESC-I | | Manufacturing Practices/ Fab Lab - I | 0 | 0 | 2 | 1 | 1 | -- | -- | -- | CIE: 100 | |
| | | | **Total** | **11** | **01** | **16** | **08** | **20** | | | | | |

## [Level 4.5, UG Certificate] Semester -II

| Sr. No. | Course Type | Course Code | Course Name | L | T | P | S | Cr | Evaluation Scheme (Weightages in %) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Theory | | | Laboratory | |
| | | | | | | | | | MSE | TA | ESE | ISE | ESE |
| 01 | BSC | MRAIBSC201 | Engineering Chemistry | 2 | 0 | 2# | 1 | 3 | 30 | 20 | 50 | CIE: 100 | |
| 02 | BSC | MRAIBSC202 | Ordinary Differential Equations and Multivariate Calculus | 2 | 1 | 0 | 1 | 3 | 30 | 20 | 50 | CIE: 100 | |
| 03 | ESC | MRAIBSC203 | Biology for Engineers | 2 | 0 | 0 | 1 | 2 | 30 | 10 | 60 | -- | -- |
| 04 | ESC | MRAIESC204 | Systems in Mechanical Engineering | 2 | 0 | 2 | 1 | 3 | 30 | 20 | 50 | CIE: 100 | |
| 05 | ESC | MRAIESC205 | Programming for Problem Solving | 1 | 0 | 2 | 2 | 2 | CIE: 100 | | | CIE: 100 | |
| 06 | ESC | MRAIESC206 | Design Thinking and Idea Lab | 0 | 0 | 2 | 1 | 1 | -- | -- | -- | CIE: 100 | |
| 07 | PCC | MRAIPCC207 | Material Science | 2 | 0 | 0 | 1 | 2 | 30 | 10 | 60 | -- | -- |
| 08 | VSEC-II | MRAIVSEC208 | Manufacturing Practices/ Fab Lab - II | 0 | 0 | 2 | 0 | 1 | -- | -- | -- | CIE: 100 | |
| 09 | IKS | MRAIIKS209 | Indian Knowledge System | 2 | 0 | 0 | 1 | 2 | CIE: 100 | | | -- | -- |
| 10 | CCA | MRAICCA210 | Co-curricular/Office Automation/ Extracurricular Activity | 0 | 0 | 2 | 0 | 1 | -- | -- | -- | CIE: 100 | |
| 11 | CEA | MRAICEA211 | Social Summer Internship-after Sem II-Exam in Sem III(60 Days) | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | -- |
| | | | **Total** | **13** | **01** | **12** | **09** | **20** | | | | | |

# => Combined Lab for Applied Chemistry and Material Science

Legends: **L**-Lecture, **T**-Tutorial, **P**-Practical, **S**-Self Study, **Cr**-Credits
**ISE**-In-Semester-Evaluation, **ESE**-End-Semester-Evaluation, **MSE**-Mid-Semester-Evaluation, **TA**-Teachers' Assessment, **CIE**-Continuous-Internal-Evaluation

| For Exit after FY -- Additional Credits for Certificate ( Any Four Skill Based Course ) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sr. No. | Course Type | Course Code | Course Name | L | T | P | S | Cr | Evaluation Scheme (Weightages in %) | | | | |
| | | | | | | | | | Theory | | | Laboratory | |
| | | | | | | | | | MSE | TA | ESE | ISE | ESE |
| 01 | VSEC | MRAIVSEC2E1 | Computer Aided Geometric Modelling | 1 | 0 | 2 | 0 | 2 | 30 | 10 | 60 | 50 | 50 |
| 02 | VSEC | MRAIVSEC2E2 | Additive Manufacturing | 1 | 0 | 2 | 0 | 2 | 30 | 10 | 60 | 50 | 50 |
| 03 | VSEC | MRAIVSEC2E3 | Metallurgical Lab Practice - I | 1 | 0 | 2 | 0 | 2 | 30 | 10 | 60 | 50 | 50 |
| 04 | VSEC | MRAIVSEC2E4 | Basics of CNC programming | 1 | 0 | 2 | 0 | 2 | 30 | 10 | 60 | 50 | 50 |
| 05 | VSEC | MRAIVSEC2E5 | Basics of Robotics & AI | 1 | 0 | 2 | 0 | 2 | 30 | 10 | 60 | 50 | 50 |
| | | | **Total** | **18** | **01** | **22** | **9** | **30** | | | | | |

*Summer internship (Industry / R&D / Academic Institute ) after IV th semester during summer Vacation & Evaluation will be done in the starting of V th Semester

# S. Y. B. Tech. Robotics & AI

## [Level 5, UG Regular] Semester -III

| Sr. No. | Course Type | Course Code | Course Name | L | T | P | S | Cr | Evaluation Scheme (Weightages in %) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Theory | | | Laboratory | |
| | | | | | | | | | MSE | TA | ESE | ISE | ESE |
| 01 | PCC | MRAIPCC301 | Basics of Robotics & AI | 3 | 0 | 0 | 1 | 3 | 30 | 20 | 50 | -- | -- |
| 02 | PCC | MRAIPCC302 | Sensors for Industrial Robotics | 2 | 0 | 2 | 1 | 3 | 30 | 20 | 50 | 50 | 50 |
| 03 | PCC | MRAIPCC303 | Industrial Robot Programming Lab | 2 | 0 | 2 | 1 | 3 | 30 | 20 | 50 | 50 | 50 |
| 04 | OE | MRAIOE304 | Open Elective - I | 3 | 0 | 0 | 1 | 3 | 30 | 20 | 50 | -- | -- |
| 05 | AEC-II | MRAIAEC305 | Indian language Sanskrit/Pali | 2 | 0 | 0 | 1 | 2 | CIE: 100 | | | -- | -- |
| 06 | VEC-I | MRAIVEC306 | Constitution of India and Universal Human Values | 1 | 0 | 0 | 0 | 1 | CIE: 100 | | | -- | -- |
| 07 | HSMC | MRAIHSMC307 | Principles of Entrepreneurship | 2 | 0 | 0 | 1 | 2 | CIE: 100 | | | -- | -- |
| 08 | CEA | MRAICEA308 | *Community Engagement Activity/ Field Project | 2 | 0 | 0 | 1 | 2 | -- | -- | -- | CIE: 100 | |
| | | | **Total** | **17** | **00** | **04** | **07** | **19** | | | | | |

* => Field project (Social) after semester II during summer vacation and evaluation will be done at the start of the III semester.

## [Level 5, UG Regular] Semester -IV

| Sr. No. | Course Type | Course Code | Course Name | L | T | P | S | Cr | Evaluation Scheme (Weightages in %) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Theory | | | Laboratory | |
| | | | | | | | | | MSE | TA | ESE | ISE | ESE |
| 01 | PCC | MRAIPCC401 | Analog & Digital Electronics | 2 | 0 | 2 | 0 | 3 | 30 | 20 | 50 | 50 | 50 |
| 02 | PCC | MRAIPCC402 | Control Systems | 2 | 0 | 2 | 0 | 3 | 30 | 20 | 50 | 50 | 50 |
| 03 | PCC | MRAIPCC403 | Drives for Robot Systems | 3 | 0 | 0 | 0 | 3 | 30 | 20 | 50 | -- | -- |
| 04 | PCC | MRAIPCC404 | Standards & Ethics for Robot Applications | 2 | 0 | 0 | 2 | 2 | CIE: 100 | | | -- | -- |
| 05 | OE-II | MRAIOE405 | Open Elective-II | 2 | 0 | 0 | 0 | 2 | 30 | 10 | 60 | -- | -- |
| 06 | MDM-I | MRAIMDM406 | Multidisciplinary Minor -I | 3 | 0 | 0 | 1 | 3 | 30 | 20 | 50 | CIE: 100 | |
| 07 | VSEC-III | MRAIVSEC407 | Numerical Methods & Programming Language | 1 | 0 | 2 | 1 | 2 | CIE: 100 | | | 50 | 50 |
| 08 | HSMC | MRAIHSMC408 | Principles of Economics | 2 | 0 | 0 | 1 | 2 | 30 | 10 | 60 | -- | -- |
| 09 | VEC-II | MRAIVEC409 | Environmental Studies | 1 | 0 | 0 | 1 | 1 | CIE: 100 | | | -- | -- |
| | | | **Total** | **18** | **00** | **06** | **06** | **21** | | | | | |

# S. Y. B. Tech. Robotics & AI

## [Level 5, UG Diploma] Semester -III Lateral Entry

| Sr. No. | Course Type | Course Code | Course Name | L | T | P | S | Cr | Evaluation Scheme (Weightages in %) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Theory | | | Laboratory | |
| | | | | | | | | | MSE | TA | ESE | ISE | ESE |
| 01 | PCC | MRAIPCC301 | Basics of Robotics & AI | 3 | 0 | 0 | 1 | 3 | 30 | 20 | 50 | -- | -- |
| 02 | PCC | MRAIPCC302 | Sensors for Industrial Robotics | 2 | 0 | 2 | 1 | 3 | 30 | 20 | 50 | 50 | 50 |
| 03 | PCC | MRAIPCC303 | Industrial Robot Programming Lab | 2 | 0 | 2 | 1 | 3 | 30 | 20 | 50 | 50 | 50 |
| 04 | OE | MRAIOE304 | Open Elective - I | 3 | 0 | 0 | 1 | 3 | 30 | 20 | 50 | -- | -- |
| 05 | AEC-II | MRAIAEC305 | Indian language Sanskrit/Pali | 2 | 0 | 0 | 1 | 2 | CIE: 100 | | | -- | -- |
| 06 | VEC-I | MRAIVEC306 | Constitution of India and Universal Human Values | 1 | 0 | 0 | 0 | 1 | CIE: 100 | | | -- | -- |
| 07 | BSC | MRAIBSC307 | Mathematics | 3 | 0 | 0 | 1 | 3 | 30 | 20 | 50 | | |
| 08 | HSMC | MRAIHSMC308 | Principles of Entrepreneurship | 2 | 0 | 0 | 1 | 2 | 30 | 10 | 60 | -- | -- |
| | | | **Total** | **18** | **00** | **04** | **07** | **20** | | | | | |

# S. Y. B. Tech. Robotics & AI

## [Level 5, UG Diploma] Semester -IV Lateral Entry

| Sr. No. | Course Type | Course Code | Course Name | L | T | P | S | Cr | Evaluation Scheme (Weightages in %) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Theory | | | Laboratory | |
| | | | | | | | | | MSE | TA | ESE | ISE | ESE |
| 01 | PCC | MRAIPCC401 | Analog & Digital Electronics | 2 | 0 | 2 | 0 | 3 | 30 | 20 | 50 | 50 | 50 |
| 02 | PCC | MRAIPCC402 | Control Systems | 2 | 0 | 2 | 0 | 3 | 30 | 20 | 50 | 50 | 50 |
| 03 | PCC | MRAIPCC403 | Drives for Robot Systems | 3 | 0 | 0 | 0 | 3 | 30 | 20 | 50 | -- | -- |
| 04 | PCC | MRAIPCC404 | Standards & Ethics for Robot Applications | 2 | 0 | 0 | 2 | 2 | CIE: 100 | | | -- | -- |
| 05 | OE-II | MRAIOE405 | Open Elective-II | 2 | 0 | 0 | 0 | 2 | 30 | 10 | 60 | -- | -- |
| 06 | MDM-I | MRAIMDM406 | Multidisciplinary Minor -I | 3 | 0 | 0 | 1 | 3 | 30 | 20 | 50 | CIE: 100 | |
| 07 | VSEC-III | MRAIVSEC407 | Numerical Methods & Programming Language | 1 | 0 | 2 | 1 | 2 | CIE: 100 | | | 50 | 50 |
| 08 | HSMC | MRAIHSMC408 | Principles of Economics | 2 | 0 | 0 | 1 | 2 | 30 | 10 | 60 | -- | -- |
| 09 | VEC-II | MRAIVEC409 | Environmental Studies | 1 | 0 | 0 | 1 | 1 | CIE: 100 | | | -- | -- |
| 10 | HSMC | MRAIHSMC410 | Communication Skills | 1 | 0 | 2 | 0 | 2 | CIE: 100 | | | CIE: 100 | |
| | | | **Total** | **19** | **00** | **08** | **06** | **23** | | | | | |

| For Exit after SY -- Additional Credits for Diploma | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sr. No.** | **Course Type** | **Course Code** | **Course Name** | **L** | **T** | **P** | **S** | **Cr** | **Evaluation Scheme (Weightages in %)** | | | | |
| | | | | | | | | | **Theory** | | | **Laboratory** | |
| | | | | | | | | | MSE | TA | ESE | ISE | ESE |
| 01 | VSEC | MRAIVSEC4E1-L | Robotic Simulation Laboratory | 0 | 1 | 2 | 0 | 2 | -- | -- | -- | 50 | 50 |
| 02 | VSEC | MRAIVSEC4E2-L | Arial Robotics Programming Lab | 0 | 1 | 2 | 2 | 2 | -- | -- | -- | 50 | 50 |
| 03 | VSEC | MRAIVSEC4E3-L | Control Systems Laboratory | 0 | 1 | 2 | 0 | 2 | -- | -- | -- | 50 | 50 |
| 04 | VSEC | MRAIVSEC4E4 | Mini Project | 0 | 2 | 0 | 0 | 2 | -- | -- | -- | CIE: 100 | |
| | | | **Total** | **19** | **05** | **14** | **8** | **31** | | | | | |
| *Summer internship (Industry / R&D / Academic Institute ) after IV th semester during summer Vacation & Evaluation will be done in the starting of V th Semester | | | | | | | | | | | | | |

Legends: **L**-Lecture, **T**-Tutorial, **P**-Practical, **S**-Self Study, **Cr**-Credits
**ISE**-In-Semester-Evaluation, **ESE**-End-Semester-Evaluation, **MSE**-Mid-Semester-Evaluation, **TA**-Teachers' Assessment, **CIE**-Continuous-Internal-Evaluation

# T. Y. B. Tech. Robotics & AI

## Semester -V

| Sr. No. | Course Type | Course Code | Course Name | L | T | P | S | Cr | Evaluation Scheme (Weightages in %) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Theory | | | Laboratory | |
| | | | | | | | | | MSE | TA | ESE | ISE | ESE |
| 01 | ELC | MRAIELC501 | Internship (Completed after Sem - IV) | 4 | 0 | 0 | 0 | 4 | CIE: 100 | | | -- | -- |
| 02 | PCC | MRAIPCC502 | Artificial Intelligence & Machine Learning | 2 | 0 | 2 | 0 | 3 | 30 | 20 | 50 | 50 | 50 |
| 03 | PCC | MRAIPCC503 | Fundamentals of Robot Manipulators | 3 | 0 | 0 | 0 | 3 | 30 | 20 | 50 | -- | -- |
| 04 | PCC | MRAIPCC504 | Signals & Systems | 2 | 0 | 2 | 2 | 3 | 30 | 20 | 50 | 50 | 50 |
| 05 | PEC-I | MRAIPEC505 | Programme Elective Course -I (Refer separate List) | 3 | 0 | 0 | 0 | 3 | 30 | 20 | 50 | -- | -- |
| 06 | PEC-II | MRAIPEC506 | Programme Elective Course -II (Refer separate List) | 3 | 0 | 0 | 0 | 3 | 30 | 20 | 50 | -- | -- |
| 07 | MDM | MRAIMDM507 | Multidisciplinary Minor - II | 3 | 0 | 0 | 0 | 3 | 30 | 20 | 50 | -- | -- |
| | | | **Total** | **20** | **0** | **04** | **02** | **22** | | | | | |

| Course Specialization / Track | Program Elective Course-I PEC-I | Program Elective Course-II PEC-II |
|---|---|---|
| Robotics | Mobile and Micro Robotics | Autonomous Robotics and Telecherics |
| AI | Data Analytics | Deep Learning |
| Mechatronics | Intelligent Manufacturing | Mechatronics System Design |
| Control Systems | Dynamic Control Systems | Microcontrollers Architecture and Programming |

## Semester -VI

| Sr. No. | Course Type | Course Code | Course Name | L | T | P | S | Cr | Evaluation Scheme (Weightages in %) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Theory | | | Laboratory | |
| | | | | | | | | | MSE | TA | ESE | ISE | ESE |
| 01 | PCC | MRAIPCC601 | Kinematics & Dynamics | 4 | 0 | 0 | 0 | 4 | 30 | 20 | 50 | -- | -- |
| 02 | PCC | MRAIPCC602-L | Robot Simulation Lab | 1 | 0 | 2 | 2 | 2 | CIE: 100 | | | 50 | 50 |
| 03 | PCC | MRAIPCC603 | Microcontrollers & It's Applications | 2 | 0 | 2 | 2 | 3 | 30 | 20 | 50 | 50 | 50 |
| 04 | PCC | MRAIPCC604 | Robot Safety & Maintenance | 2 | 0 | 0 | 1 | 2 | 30 | 10 | 60 | -- | -- |
| 05 | PCC | MRAIPCC605 | Data Science | 3 | 0 | 0 | 2 | 3 | 30 | 20 | 50 | 50 | 50 |
| 06 | PCC | MRAIPCC606 | Seminar on recent advances in R & AI | 0 | 0 | 2 | 0 | 1 | -- | -- | -- | 50 | 50 |
| 07 | VSEC | MRAIVSEC607-L | Arial Robotics Lab | 0 | 0 | 2 | 0 | 1 | 30 | 10 | 60 | -- | -- |
| 08 | MDM | MRAIMDM608 | Multidisciplinary Minor - III | 4 | 0 | 0 | 0 | 4 | 30 | 20 | 50 | -- | -- |
| 09 | OE-III | MRAIOE609 | Open Elective -III | 2 | 0 | 0 | 0 | 2 | 30 | 10 | 60 | -- | -- |
| 10 | ELC | MRAIELC610 | Summer Internship-after Sem VI-Exam in Sem VII | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | -- |
| | | | **Total** | **18** | **0** | **8** | **7** | **22** | | | | | |

| For Exit after TY-- Additional Credits for B Vocational | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sr. No.** | **Course Type** | **Course Code** | **Course Name** | **L** | **T** | **P** | **S** | **Cr** | **Evaluation Scheme (Weightages in %)** | | | | |
| | | | | | | | | | **Theory** | | | **Laboratory** | |
| | | | | | | | | | MSE | TA | ESE | ISE | ESE |
| 01 | VSEC | MRAIVSEC6E1-L | Robot Operating System | 0 | 0 | 4 | 0 | 2 | -- | -- | -- | 50 | 50 |
| 02 | VSEC | MRAIVSEC6E2-L | Autonomous Navigation Lab using SLAM | 0 | 0 | 4 | 0 | 2 | -- | -- | -- | 50 | 50 |
| 03 | VSEC | MRAIVSEC6E3 | Robot System Design | 2 | 0 | 0 | 2 | 2 | 30 | 10 | 60 | -- | -- |
| 04 | VSEC | MRAIVSEC6E4 | Mini Project | 2 | 0 | 0 | 0 | 2 | -- | -- | -- | CIE: 100 | |
| | | | **Total** | **22** | **0** | **16** | **9** | **30** | | | | | |
| *Summer internship (Industry / R&D / Academic Institute ) after IV th semester during summer Vacation & Evaluation will be done in the starting of V th Semester | | | | | | | | | | | | | |

Legends: **L**-Lecture, **T**-Tutorial, **P**-Practical, **S**-Self Study, **Cr**-Credits
**ISE**-In-Semester-Evaluation, **ESE**-End-Semester-Evaluation, **MSE**-Mid-Semester-Evaluation, **TA**-Teachers' Assessment, **CIE**-Continuous-Internal-Evaluation

# B. Tech. Robotics & AI

## Semester -VII

| **Sr. No.** | **Course Type** | **Course Code** | **Course Name** | **L** | **T** | **P** | **S** | **Cr** | **Evaluation Scheme (Weightages in %)** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | **Theory** | | | **Laboratory** | |
| | | | | | | | | | MSE | TA | ESE | ISE | ESE |
| 01 | ELC | MRAIELC701 | Internship (Completed after Sem - VI) | 4 | 0 | 0 | 0 | 4 | -- | -- | -- | CIE: 100 | |
| 02 | PEC-III | MRAIPEC702 | Programme Elective Course -III (Refer separate List) | 3 | 0 | 0 | 0 | 3 | 30 | 20 | 50 | -- | -- |
| 03 | PEC-IV | MRAIPEC703 | Programme Elective Course -IV (Refer separate List) | 3 | 0 | 0 | 0 | 3 | 30 | 20 | 50 | -- | -- |
| 04 | PCC | MRAIPCC704 | ROS & SLAM Laboratory | 0 | 0 | 4 | 0 | 2 | -- | -- | -- | 50 | 50 |
| 06 | PCC | MRAIPCC706 | Robot operating System | 4 | 0 | 0 | 0 | 4 | 30 | 20 | 50 | -- | -- |
| 07 | RM | MRAIRM707 | Research Methodology | 2 | 0 | 0 | 1 | 2 | 30 | 10 | 60 | -- | -- |
| 08 | MDM | MRAIMDM708 | Multidisciplinary Minor-IV | 4 | 0 | 0 | 0 | 4 | 30 | 20 | 50 | -- | -- |
| | | | **Total** | **20** | **0** | **4** | **3** | **22** | | | | | |

| **Course Specialization / Track** | **Program Elective Course-III PEC-III** | **Program Elective Course-IV PEC-IV** |
|---|---|---|
| Robotics | Advanced Robotics Programming | Biomedical Robotics |
| AI | Advanced Artificial Intelligence | Augmented Reality and Virtual Reality |
| Mechatronics | Micro electromechanical Systems | Advanced Mechatronics |
| Control Systems | Advanced Control System | Robot Dynamics and Control |

## Semester -VIII

| Sr. No. | Course Type | Course Code | Course Name | L | T | P | S | Cr | Evaluation Scheme (Weightages in %) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Theory | | | Laboratory | |
| | | | | | | | | | MSE | TA | ESE | ISE | ESE |
| 01 | PEC-V | MRAIPEC801 | Programme Elective Course -V (Refer separate List) / MOOCS | 3 | 0 | 0 | 0 | 3 | 30 | 20 | 50 | -- | -- |
| 02 | PEC-VI | MRAIPEC802 | Programme Elective Course -VI (Refer separate List) / MOOCS | 3 | 0 | 0 | 0 | 3 | 30 | 20 | 50 | -- | -- |
| 03 | ELC | MRAIELC803 | Internship / Project | 0 | 0 | 16 | 5 | 8 | -- | -- | -- | CIE: 100 | |
| | | | **Total** | **6** | **0** | **16** | **5** | **14** | | | | | |

| Course Specialization / Track | Program Elective Course-V PEC-V | Program Elective Course-VI PEC-VI |
|---|---|---|
| Robotics | Agricultural Robotics | Medical Robotics Technology |
| AI | AI based Agriculture | AI for Medical Applications |
| Mechatronics | Mechatronics for Agriculture | Mechatronics for Medical Applications |
| Control Systems | Agricultural Plant & Device Control | Control for Biomedical Instrumentation systems |

Legends: **L**-Lecture, **T**-Tutorial, **P**-Practical, **S**-Self Study, **Cr**-Credits
**ISE**-In-Semester-Evaluation, **ESE**-End-Semester-Evaluation, **MSE**-Mid-Semester-Evaluation, **TA**-Teachers' Assessment, **CIE**-Continuous-Internal-Evaluation

| Sr No | Semester | Teaching Scheme | | | | Total | Credit |
|---|---|---|---|---|---|---|---|
| | | L | T | P | SS | | |
| 1 | I | 11 | 01 | 16 | 06 | 34 | 20 |
| 2 | II | 13 | 01 | 12 | 02 | 28 | 20 |
| 3 | III | 15 | 00 | 08 | 05 | 28 | 19 |
| 4 | IV | 18 | 00 | 06 | 06 | 30 | 21 |
| 5 | V | 20 | 0 | 04 | 02 | 26 | 22 |
| 6 | VI | 18 | 0 | 08 | 07 | 33 | 22 |
| 7 | VII | 20 | 0 | 04 | 03 | 27 | 22 |
| 8 | VIII | 06 | 0 | 16 | 05 | 22 | 14 |
| | **Total** | **121** | **2** | **74** | **36** | **218** | **160** |

### Internship courses

| Sr. No. | Course Type | Course Code | Course Name | L | T | P | S | Cr | Evaluation Scheme (Weightages in %) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Theory | | | Laboratory | |
| | | | | | | | | | MSE | TA | ESE | ISE | ESE |
| 01 | CEA | MRAICEA211 | Social Summer Internship-after Sem II-Exam in Sem III | 2 | 0 | 0 | 0 | 2 | -- | -- | -- | CIE: 100 | |
| 02 | ELC | MRAIELC410 | Summer Internship-after Sem IV-Exam in Sem V | 4 | 0 | 0 | 0 | 4 | -- | -- | -- | CIE: 100 | |
| 03 | ELC | MRAIELC610 | Summer Internship-after Sem VI-Exam in Sem VII | 4 | 0 | 0 | 0 | 4 | -- | -- | -- | CIE: 100 | |

### Open Electives ( Robotics )

| Sr. No. | SEM | Course Type | Course Name | L | T | P | S | Cr | Evaluation Scheme (Weightages in %) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Theory | | | Laboratory | |
| | | | | | | | | | MSE | TA | ESE | ISE | ESE |
| 01 | III | OE- I | Mobile and Micro Robotics | 2 | 0 | 0 | 2 | 2 | 30 | 10 | 60 | -- | -- |
| 02 | IV | OE- II | Autonomous Robotics & Telecherics | 2 | 0 | 0 | 2 | 2 | 30 | 10 | 60 | -- | -- |
| 03 | V | OE- III | Advanced Robotics Programming | 2 | 0 | 0 | 2 | 2 | 30 | 10 | 60 | -- | -- |

### Open Electives (Artificial Intelligence)

| Sr. No. | SEM | Course Type | Course Name | L | T | P | S | Cr | Evaluation Scheme (Weightages in %) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Theory | | | Laboratory | |
| | | | | | | | | | MSE | TA | ESE | ISE | ESE |
| 01 | III | OE- I | Data Analytics | 2 | 0 | 0 | 2 | 2 | 30 | 10 | 60 | -- | -- |
| 02 | IV | OE- II | Deep Learning | 2 | 0 | 0 | 2 | 2 | 30 | 10 | 60 | -- | -- |
| 03 | V | OE- III | Advanced Artificial Intelligence | 2 | 0 | 0 | 2 | 2 | 30 | 10 | 60 | -- | -- |

### Multidisciplinary Minors – for other Branches

| Sr. No. | SEM | Course Type | Course Name | L | T | P | S | Cr | Evaluation Scheme (Weightages in %) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Theory | | | Laboratory | |
| | | | | | | | | | MSE | TA | ESE | ISE | ESE |
| 01 | IV | MDM I | Drives for Industrial Robotics | 3 | 0 | 0 | 0 | 3 | 30 | 20 | 50 | -- | -- |
| 02 | V | MDM II | Fundamentals of Robot Manipulators | 3 | 0 | 0 | 0 | 3 | 30 | 20 | 50 | -- | -- |
| 03 | VI | MDM III | Kinematics & Dynamics | 4 | 0 | 0 | 0 | 4 | 30 | 20 | 50 | -- | -- |
| 04 | VII | MDM IV | Robot Operating System | 4 | 0 | 0 | 0 | 4 | 30 | 20 | 50 | -- | -- |
| | | | **Total** | **14** | **0** | **0** | **0** | **14** | | | | | |

## Double minors – for other Branches

| Sr. No. | SEM | Course Type | Course Name | L | T | P | S | Cr | Evaluation Scheme (Weightages in %) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Theory | | | Laboratory | |
| | | | | | | | | | MSE | TA | ESE | ISE | ESE |
| 01 | IV | MDM I | Analog & Digital Electronics | 2 | 0 | 2 | 2 | 3 | 30 | 20 | 50 | 50 | 50 |
| 02 | V | MDM II | Signals & Systems | 2 | 0 | 2 | 2 | 3 | 30 | 20 | 50 | 50 | 50 |
| 03 | VI | MDM III | Microcontrollers & It's Applications | 2 | 1 | 2 | 2 | 4 | 30 | 20 | 50 | 50 | 50 |
| 04 | VII | MDM IV | ROS & SLAM Laboratory | 0 | 2 | 4 | 2 | 4 | 30 | 20 | 50 | 50 | 50 |
| | | | **Total** | **6** | **3** | **10** | **8** | **14** | | | | | |

## Honors – Robotics Engineering – for other Branches

| Sr. No. | SEM | Course Name | L | T | P | S | Cr | Evaluation Scheme (Weightages in %) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Theory | | | Laboratory | |
| | | | | | | | | MSE | TA | ESE | ISE | ESE |
| 01 | III | Sensors for Industrial Robotics | 2 | 1 | 2 | 0 | 4 | 30 | 20 | 50 | 50 | 50 |
| 02 | IV | Drives for Industrial Robotics | 3 | 1 | 0 | 0 | 4 | 30 | 20 | 50 | -- | -- |
| 03 | V | Fundamentals of Robot Manipulators | 3 | 1 | 0 | 0 | 4 | 30 | 20 | 50 | -- | -- |
| 04 | VI | Kinematics & Dynamics | 4 | 0 | 0 | 2 | 4 | 30 | 20 | 50 | -- | -- |
| 05 | VII | Robot Operating System | 4 | 0 | 0 | 2 | 4 | 30 | 20 | 50 | -- | -- |
| | | Total | **16** | **3** | **2** | **4** | **20** | | | | | |

## Honors – Artificial Intelligence – for other Branches

| Sr. No. | SEM | Course Name | L | T | P | S | Cr | Evaluation Scheme (Weightages in %) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Theory | | | Laboratory | |
| | | | | | | | | MSE | TA | ESE | ISE | ESE |
| 01 | III | Basics of Robotics & AI | 2 | 2 | 0 | 0 | 3 | 30 | 10 | 60 | -- | -- |
| 02 | IV | Data Science | 3 | 1 | 0 | 2 | 4 | 30 | 10 | 60 | -- | -- |
| 03 | V | Artificial Intelligence & Machine Learning | 2 | 1 | 2 | 0 | 4 | 30 | 10 | 60 | 50 | 50 |
| 04 | VI | Robot Operating System | 4 | 0 | 0 | 0 | 4 | 30 | 20 | 50 | -- | -- |
| 05 | VII | Advanced Artificial Intelligence | 2 | 2 | 0 | 2 | 4 | 30 | 10 | 60 | -- | -- |
| | | **Total** | **13** | **6** | **2** | **4** | **20** | | | | | |

## Honors – Research

| Sr. No. | SEM | Course Name | L | T | P | S | Cr | Evaluation Scheme (Weightages in %) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Theory | | | Laboratory | |
| | | | | | | | | MSE | TA | ESE | ISE | ESE |
| 01 | III | Problem Identification and Definition | 3 | 1 | - | 2 | 4 | 30 | 20 | 50 | -- | -- |
| 02 | IV | Literature Review | 3 | 1 | - | 2 | 4 | 30 | 20 | 50 | -- | -- |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 03 | V | Experimental Work/Analytical Tools and Prototype Development | 3 | 1 | - | 2 | 4 | 30 | 20 | 50 | -- | -- |
| 04 | VI | Data Analysis | 3 | 1 | - | 2 | 4 | 30 | 20 | 50 | -- | -- |
| 05 | VII | Publication | 3 | 1 | - | 2 | 4 | 30 | 20 | 50 | -- | -- |
| | | **Total** | **15** | **5** | **-** | **10** | **20** | | | | | |

## B. Tech Honors with Research

| Sr. No. | SEM | Course Name | L | T | P | S | Cr | Evaluation Scheme (Weightages in %) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Theory | | | Laboratory | |
| | | | | | | | | MSE | TA | ESE | ISE | ESE |
| 04 | VI | Research Project ( Part 1) Problem Identification and Definition, Literature Review, Experimental Work | - | 2 | - | 20 | 10 | -- | -- | -- | CIE: 100 | |
| 05 | VII | Research Project ( Part 2) Prototype Development, Data Analysis, Publication | - | 2 | - | 20 | 10 | -- | -- | -- | CIE: 100 | |
| | | **Total** | **-** | **4** | **-** | **40** | **20** | | | | | |

**Honors- B. Tech. ( Robotics & Artificial Intelligence )**

**For Honors in Mechanical Engineering, students should select below courses of 20 credits from the pool of electives given below. These selected courses should not be part of mandatory 160 regular credits.**

| Course Specialization / Track | Program Elective Course-I PEC-I | Program Elective Course-II PEC-II |
|---|---|---|
| Robotics | Mobile and Micro Robotics | Autonomous Robotics and Telecherics |
| AI | Data Analytics | Deep Learning |
| Mechatronics | Intelligent Manufacturing | Mechatronics System Design |
| Control Systems | Dynamic Control Systems | Microcontrollers Architecture and Programming |

| Course Specialization / Track | Program Elective Course-III PEC-III | Program Elective Course-IV PEC-IV |
|---|---|---|
| Robotics | Advanced Robotics Programming | Biomedical Robotics |
| AI | Advanced Artificial Intelligence | Augmented Reality and Virtual Reality |
| Mechatronics | Micro electromechanical Systems | Advanced Mechatronics |
| Control Systems | Advanced Control System | Robot Dynamics and Control |

| Course Specialization / Track | Program Elective Course-V PEC-V | Program Elective Course-VI PEC-VI |
|---|---|---|
| Robotics | Agricultural Robotics | Medical Robotics Technology |
| AI | AI based Agriculture | AI for Medical Applications |
| Mechatronics | Mechatronics for Agriculture | Mechatronics for Medical Applications |
| Control Systems | Agricultural Plant & Device Control | Control for Biomedical Instrumentation systems |

# Semester -III

### Course: Basics of Robotics and AI

| **Course Code** | MRAIPCC301 | **Scheme of Evaluation** | MSE, TA & ESE |
|---|---|---|---|
| **Teaching Plan** | **3-0-0-1** | **Mid Semester Exam** | 30 |
| **Credits** | 3 | **Teachers' Assessment** | 20 |
| | | **End Semester Evaluation** | 50 |

**Course Outcomes:**

Students who successfully complete this course will have demonstrated an ability to:

1. Differentiate types of robots and robot grippers and compare & classify types of Sensors, drives & Grippers
2. Apply robot kinematics principals for understanding manipulators tracking
3. Apply basic principles of AI in solutions that require problem solving, inference, perception, knowledge representation and learning by understanding AI, its current scope and limitations, and societal implications.
4. Demonstrate awareness and a fundamental understanding of AI techniques in intelligent agents, artificial neural networks.
5. Model forward and inverse kinematics of robot manipulator.

**Syllabus:**

| Unit | Contents | Lecture |
|---|---|---|
| **1** | **Introduction:**<br>Basics of Robotics, Definitions, Laws & Robotics-classification with respect to geometrical configuration (Anatomy), Industrial robots specifications. Selection based on the Application. Controlled system & chain type: Serial manipulator & Parallel Manipulator. Components of Industrial robotics-precession of movement-resolution, accuracy & repeatability. Advances in Industrial Robotics Technology<br>Robot Applications: Material transfer and machine loading/unloading, processing operations assembly and inspection. | 7 Hrs |
| **2** | **Sensors**<br>Characteristics of sensing devices, Criterion for selections of sensors, Classification, & applications of sensors.<br>**Controllers**<br>Types of Controller and introduction to close loop controller.<br>**Programming and Languages**<br>Methods of robot programming, Introduction to various languages such as RAIL and VAL II …etc. | 6 Hrs |
| **3** | **Drives**<br>Types of drives. Advantages and Disadvantages of each type, Selection / suitability of drives for Robotic application.<br>**Grippers**<br>Classification of Grippers, Mechanical Gripper-Grasping force, mechanisms for actuation, Magnetic gripper vacuum cup gripper-considerations in gripper selection & design. | 6 Hrs |
| **4** | **Introduction to Artificial Intelligence:**<br>Overview: foundations, scope, problems, and approaches of AI. Intelligent agents: reactive, deliberative, goal-driven, utility-driven, and learning agents, Artificial Intelligence programming techniques. | 6 Hrs |
| **5** | **Problem-solving Approaches:**<br>Forward and backward, state-space, blind, heuristic, problem reduction, alpha-beta pruning, minimax, constraint propagation, neural, stochastic, and evolutionary search algorithms, sample applications. | 5 Hrs |
| **6** | **Knowledge Representation and Reasoning:**<br>Ontologies, foundations of knowledge representation and reasoning, representing, and reasoning about objects, relations, events, actions, time, | 6 Hrs |

| | | |
|---|---|---|
| | and space; predicate logic, situation calculus, description logics, reasoning with defaults, reasoning about knowledge, sample applications. | |

**Suggested learning resources:**

**Textbooks:**

1. John J. Craig, Introduction to Robotics, Pearson Education Inc., Asia, 3rd Edition, 2005
2. Asitava Ghoshal, Robotics: Fundamental concepts & analysis, Oxford University Press, 2006
3. Luger " Artificial Intelligence", Edition 5, Pearson, 2008
4. Dilip Kumar Pratihar, Fundamentals of Robotics, Narosa Publishing House, 2019
5. R. K. Mittal, et. al., Robotics & Control, TATA McGraw Hill Pub. Co Ltd, New Delhi 2003
6. Michael Negnevitsky, Artificial Intelligence: A Guide to Intelligent Systems (3rd Ed), 2011
7. Vinod Chandra S.S., Anand H S, " Artificial Intelligence & Machine Learning", 2014

**Reference Books:**

1. S. K. Saha, Introduction to Robotics, TATA McGraw Hills Education ,2014
2. S. B. Nikku, Introduction to Robotics – Analysis, Control, Applications, 3rd edition, John Wiley & Sons Ltd., 2020
3. Mikell Groover, Mitchell Weiss, Roger N. Nagel, Nicholas Odrey, Ashish Dutta, Industrial Robotics 2nd edition, SIE , McGraw Hill Education (India) Pvt Ltd, 2012
4. R. D. Klafter, Thomas A. Chmielewski, and Michael Negin, Robotic Engineering – An Integrated Approach, EEE, Prentice Hall India, Pearson Education Inc., 2009
5. Russell, S & Norvig, Peter, Artificial Intelligence: A Modern Approach, Prentice Hall, 2003.
6. Aleksander, Igor and Burnett, Piers ,Thinking Machines Oxford, 1987.
7. Bench-Capon, T. J. M., Knowledge Representation: An approach to artificial intelligence Academic Press, 1990.
8. Genesereth, Michael R. and Nilsson, Nils J, Logical Foundations of Artificial Intelligence Morgan Kaufmann,1987.

**Course: Sensors for Industrial Robotics**

| **Course Code** | MRAIPCC302 | **Scheme of Evaluation** | MSE & ESE |
|---|---|---|---|
| **Teaching Plan** | 2-0-2-1 | **Mid Semester Exam** | 30 |
| **Credits** | 2 | **Teachers' Assessment** | 20 |
| | | **End Semester Evaluation** | 50 |

**Course Outcome:**

Students who successfully complete this course will have demonstrated an ability to:

1. Identify suitable sensor for robotic applications.
2. Compare & classify types of Sensors
3. Apply basic principles of system integration for system integration.
4. Demonstrate awareness and a fundamental understanding of all types robotic sensors.

**Syllabus:**

| **Unit** | **Contents** | **Lecture** |
|---|---|---|
| **1** | **Sensor Fundamentals:** | 6 Hrs |

| | | |
|---|---|---|
| | Overview of sensors and their role in robotics, Types of sensors used in robotics applications, Sensor characteristics: accuracy, precision, range, resolution, etc. Principles of sensing: electrical, optical, mechanical, etc. Sensor classification: contact, non-contact, proximity, etc., Sensor signal conditioning and amplification | |
| **2** | **Sensor Types and Applications:**<br>Vision sensors and cameras, Range, and proximity sensors (ultrasonic, infrared, etc.), Force and tactile sensors. Motion and position sensors (encoders, accelerometers, etc.), Environmental sensors (temperature, humidity, etc.), Smart Sensors , Robot perception and environment sensing, Navigation and localization using sensors, Object detection and recognition, Grasping and manipulation with sensors, Human-robot interaction and sensing | 6 Hrs |
| **3** | **Sensor Integration and Calibration:**<br>Sensor mounting and placement in robotic systems, Sensor fusion and data integration, Sensor calibration and error compensation, Signal processing techniques for sensor data, Filtering and noise reduction, Feature extraction and pattern recognition. | 6 Hrs |
| **4** | **Emerging Sensor Technologies and Trends:**<br>Advancements in sensor technologies (e.g., LiDAR, depth sensors), MEMS Sensors, Sensor networks and Internet of Things (IoT) in robotics, Sensor-based feedback control and closed-loop systems, Biomimetic tactile Sensors based on Nanomaterials, Recent Advances in biomimetic sensing technology, Ionic Polymer and Metal composites as biomimetic Sensors and Actuators, Applications of Sensors | 6 Hrs |

**Suggested learning resources:**

**Textbooks:**


1 Patranabis D, “Sensors and Transducers”, 2nd Edition, PHI, New Delhi, 2013
2 Ernest O Doebelin, “Measurement Systems – Applications and Design”, Tata McGraw-Hill, 2009
3. Peter Elgar, "Sensors for Measurement & Control", Adison-Wesley Longman Ltd, 1998.


**Reference Books:**


1 Fraden, J., “Handbook of modern sensors : physics, designs, and applications”, Springer, New York, 2004
2 C. Sujatha Dyer, S. A., Survey of Instrumentation and Measurement, John Wiley & Sons, Canada, 2001
3 Jon S. Wilson, Sensor Technology Handbook, Elsevier, 2005
4 Toko, K., “Biomimetic sensor technology”, Cambridge Univ Press, Cambridge, 2000
5 Hans Kurt Tönshoff (Editor), Ichiro, “Sensors in Manufacturing” Volume 1, Wiley-VCH April 2001.
6 Richard Zurawski, “Industrial Communication Technology Handbook” 2nd edition, CRC Press, 2015
7 Robert B. Northrop , "Introduction to Instrumentation and Measurements", 3rd Edition, CRC Press, 2014.


**Course: Sensors for Industrial Robotics Laboratory**

| | | | |
|---|---|---|---|
| **Course Code** | MRAIPCC302-L | **Scheme of Evaluation** | MSE & ESE |
| **Teaching Plan** | 2-0-2-0 | **Term Work** | 50 |

| Credits | 1 | Oral Exam | 50 |
|---|---|---|---|

**Course Outcome:**

Students who successfully complete this course will have demonstrated an ability to:

1. Understand the principles behind various sensors used in industrial robotics.
2. Select appropriate sensors for different robotic applications.
3. Interface sensors with robotic systems and interpret their output.
4. Analyze sensor data to make decisions in robotic control systems.
5. Troubleshoot common issues related to sensor integration in industrial robotics.

**Course Contents: Assignments / Practical based on:**

Detailed Content : Any six experiments / assignments from the list below (Total Min. 24 Hours)

| Expt. No. | Contents | Contact Hours |
|---|---|---|
| **1** | Proximity Sensors<br>Understand principles of operation of capacitive, inductive, and optical proximity sensors and learn Calibration and testing of proximity sensors | 4 Hrs |
| **2** | Vision Systems<br>Understand machine vision and image processing for object detection and recognition | 4 Hrs |
| **3** | Force/Torque Sensors<br>Understand force and torque sensing principles and Types of force/torque sensors: strain gauge, piezoelectric, etc. and learn the force/torque sensing in industrial robotics | 4 Hrs |
| **4** | Temperature and Pressure Sensors<br>Understand temperature and pressure sensing technologies and attempt integration of temperature and pressure sensors in robotic systems. | 4 Hrs |
| **5** | Motion and Position Sensors<br>Understand principles of motion and position sensing, Encoders, accelerometers, and gyroscopes applications of motion and position sensors in robotics | 4 Hrs |
| **6** | Sensor Fusion and Integration<br>Understand Principles of motion and position sensing, encoders, accelerometers, and gyroscopes and implement applications of motion and position sensors in robotics | 4 Hrs |
| **7** | Advanced Topics and Emerging Trends<br>Short seminar on a Recent advancement in any one specific type of sensor technologies for industrial robotics, on an Integration of AI and machine learning with sensor data, on an Ethical considerations and challenges in sensor-enabled robotics …etc | 4 Hrs |
| **8** | Mini Project Work<br>Students work on a mini project where they apply their knowledge of sensors in industrial robotics to solve a real-world problem or develop an innovative application. | 4 Hrs |

**Text Books:**

1. Sensors and Actuators in Mechatronics: Design and Applications" by Andrzej M. Pawlak, CRC Press, 2018

2. Introduction to Autonomous Robots: Mechanics, Sensors, Actuators, and Algorithms by Nikolaus Correll, Bradley Hayes, and Amirhossein Memarzadeh, Chapman and Hall/CRC, 2019
3. Industrial Sensors and Instrumentation by C. J. S. De Silva, CRC Press, 2017
4. Sensors for Mechatronics by Paul P. L. Regtien, Elsevier, 2012

## Course: Industrial Robot Programming

| **Course Code** | MRAIPCC303 | **Scheme of Evaluation** | MSE & ESE |
|---|---|---|---|
| **Teaching Plan** | 2-0-2-1 | **Mid Semester Exam** | 30 |
| **Credits** | 2 | **Teachers' Assessment** | 20 |
| | | **End Semester Evaluation** | 50 |

**Course Outcome:**
Students who successfully complete this course will have demonstrated an ability to:

1. Identify and explain the core principles of industrial robots.
2. Program robots using different methods.
3. Implement fundamental robot programming concepts.
4. Apply advanced robot programming techniques.
5. Develop robot programs for industrial applications.

| Unit | Contents | Lecture |
|---|---|---|
| 1 | **Introduction to Industrial Robotics**<br>Fundamentals of Robotics: Definition, functions, advantages, disadvantages, applications of robots.<br>Robot Anatomy: Classification (SCARA, Cartesian, Articulated etc.), components (manipulator, end-effector, controller, sensors, actuators).<br>Robot Specifications: Work envelope, payload capacity, repeatability, degrees of freedom. | 6 Hrs |
| 2 | **Robot Programming Fundamentals**<br>Programming Methods: Lead-through programming, teach pendant, offline programming, text-based programming.<br>Robot Programming Concepts: Motion control commands (MOVE, WAIT, SIGNAL, DELAY), subroutines, branching, error handling.<br>Robot Programming Languages: Generations of robot languages, introduction to specific languages (e.g., VAL, RAIL, AML) and modern trends (Python, ROS). | 6 Hrs |
| 3 | **Advanced Robot Programming Techniques**<br>Sensor Integration: Tactile, position, velocity, and force sensors for robot interaction and feedback.<br>Path planning and Interpolation: Techniques for generating smooth robot motion paths between programmed points.<br>Vision Systems for Robotics: Introduction to robot vision systems, image processing basics for object recognition and grasping.<br>Safety Programming: Emergency stop procedures, safety interlocks, robot programming considerations for safe operation. | 6 Hrs |
| 4 | **Industrial Robot Programming Applications** | 6 Hrs |

| | | |
|---|---|---|
| | Case Studies: Programming examples for common industrial applications (e.g., welding, painting, material handling, assembly).<br>Simulation and Offline Programming: Utilizing robot simulation software to create, test, and debug robot programs.<br>Troubleshooting and Maintenance: Identifying and resolving common robot programming errors, basic robot maintenance procedures.<br>Future Trends in Industrial Robotics: Advanced programming techniques, collaborative robots (cobots), and the integration of artificial intelligence (AI). | |

**Suggested learning resources:**

1. Industrial Robotics by Yoram Koren (5th Edition)
2. Robot Programming: Robot Languages and Robot Communication by Richard D. Wright and Matthew P. McLaughlin
3. Robotics, Vision & Control: Fundamentals & Advanced Applications by Farid Kendoul
4. Robot Programming: A Guide to Using RUIP with ABB Robots by Rick Young

## Course: Industrial Robot Programming Laboratory

| Course Code | MRAIPCC303-L | Scheme of Evaluation | MSE & ESE |
|---|---|---|---|
| **Teaching Plan** | 2-0-2-1 | **Term Work** | 50 |
| **Credits** | 1 | **Oral Exam** | 50 |

**Course Outcome:**

Students who successfully complete this course will have demonstrated an ability to:

1. Use fundamental and technical knowledge of robot Programming
2. Learn Robot Programming using teach Pendant for various applications
3. Use RAPID Language and AML
4. Program a Robot for Industrial applications
5. Program using Robot studio software

**Course Contents: Assignments / Practical based on:**

Detailed Content: Any eight experiments / assignments from the list below (Total Min. 24 Hours)

| Expt. No. | Contents | Contact Hours |
|---|---|---|
| **1** | Understand max reach and speed limits for each joint. Also identify the type of workspace accordingly. | 2 Hrs |
| **2** | Robot Programming – Walk through programming | 4 Hrs |
| **3** | Robot Programming using Teach Pendant- Lead through programming including Coordinate systems of Robot. | 4 Hrs |
| **4** | Wrist Mechanism-Interpolation-Interlock commands | 2 Hrs |
| **5** | VAL language commands motion control, hand control, program control, pick and place applications | 4 Hrs |
| **6** | Palletizing applications | 2 Hrs |
| **7** | Object detection and Sorting | 2 Hrs |
| **8** | Robot welding application | 4 Hrs |
| **9** | RAPID Language and AML | 2 Hrs |

| | | |
|---|---|---|
| **10** | Programming using Robot simulation software | 4 Hrs |

**Suggested learning resources:**

**Textbooks:**

1. Hughes Cameron, "Robot Programming", Pearson Publishers, 2016
2. J. Srinivas, "Robotics: Control and Programming", Narosa Publication, 2009

**Reference Books:**

1. Lentin Joseph, "Learning Robotics Using Python", Second Edition Design, simulate, program, and prototype an autonomous mobile robot using ROS, OpenCV, PCL, and Python, Packt Publishing Paperback – 1 January 2018
2. Staple Danny, "Learn Robotics Programming", Packt Publishing Limited, Feb 2021
3. Kailashi Chandra Mahajan, Prashant Kumar Patnaik, Raghvendra Kumar, "Robotics for Engineers", Vikas Publishing House , 2016

**Open Elective -I**
**Indian language Sanskrit/Pali**
**Constitution of India and Universal Human Values**
**Principles of Entrepreneurship**
**[Note- Above subject's syllabus will be from respective department]**

# Semester -IV

**Course: Analog & Digital Electronics**

| **Course Code** | MRAIPCC401 | **Scheme of Evaluation** | MSE, PTE & ESE |
|---|---|---|---|
| **Teaching Plan** | 2-0-2-0 | **Mid Semester Exam** | 30 |
| **Credits** | 2 | **Teachers' Assessment** | 20 |
| | | **End Sem Exam** | 50 |

**Course Outcomes:**

At the end of the course, students will demonstrate the ability to,

1. Design and Analyze Analog sub-circuits using BJT and FET.
2. Design & analyze modular combinational circuits with MSI devices like MUX/DEMUX, Decoder, Encoder, etc
3. Design the linear and non-linear applications of Op-Amp.
4. Design & analyze synchronous sequential logic circuits with FFs and combinatorial circuits.
5. Design & analyze modular combinational circuits with MSI devices like MUX/DEMUX, Decoder, Encoder, etc

**Syllabus:**

| Unit | Contents | Lecture |
|---|---|---|
| **1** | **Physics of Bipolar Junction Transistors**<br>Structure of NPN and PNP Transistors, Energy-Band Diagram, Operation of BJT, I/V characteristics, Large Signal model, Small signal model, Concept of transconductance, Early Effect. Bipolar amplifier: CE, CC &CB Physics of MOS Transistors: Structure of N and P MOSFET, Energy-Band Diagram, Operation of MOSFET, Channel Length Modulation, CMOS Technology, Comparison of Bipolar & MOS Devices | 4 Hrs |
| **2** | **Fundamentals of Op-Amp**<br>Op-Amp parameters Circuits with resistive feedback: Concept of feedback & their types, Inverting & non-inverting configurations, current to voltage converters, voltage to current converters, summing amplifier, difference amplifier, instrumentation amplifier.<br>**Non-linear circuits**<br>Schmitt trigger, Voltage comparators, comparator applications, precision rectifiers, analog switches, peak detectors, sample & hold circuits, Integrators & differentiators, Clippers and Clampers Feedback & Oscillator Circuit: Effect of positive and negative feedback, Analysis of practical feedback amplifiers, Sinusoidal Oscillators (RC, LC and Crystal), Multivibrators using 555 timer. | 8 Hrs |
| **3** | **Logic Simplification and Combinational Logic Design**<br>Review of Boolean Algebra and De Morgan's Theorem, SOP & POS forms, Canonical forms, Karnaugh maps up to 6 variables, Binary codes, Code Conversion. MSI devices like Multiplexers, Encoder, Decoder, Comparators, Half and Full Adders, Subtractors, BCD Adder, Barrel shifter and ALU.<br>**Sequential Logic Design**<br>Building blocks like S-R, JK and D latch, Master-Slave JK FF, Edge triggered FF, Ripple and Synchronous counters, Shift registers, Finite state machines, Design of synchronous FSM. | 8 Hrs |
| **4** | **Logic Families and Semiconductor Memories**<br>TTL NAND gate, Specifications, Noise margin, Propagation delay, fan-in, fan-out, Tristate TTL, ECL, CMOS families and their interfacing, Memory elements, Concept of PLDs like PAL, PLA, CPLDs, FPGA etc. Logic implementation using Programmable Devices (ROM, PLA) | 4 Hrs |

**Suggested learning resources:**

**Textbooks:**

1. Behzad Razavi , “Fundamentals of Microelectronics” , Second Edition; Wiley, 2016.
2. Ramakant A Gaikwad, “Op-Amps and Linear Integrated Circuits”, PHI, 4th edition,2016

**Reference Books:**

1. Thomas L Floyd, “Electronic Devices”, 10th edition, Pearson, 2017
2. G. B. Clayton, “Operational Amplifiers”, International Edition, 2nd Edition,1979.
3. Anand Kumar, “Fundamentals of Digital circuits”, PHI, Fourth edition, 2016.
4. R.P. Jain, “Modern digital Electronics”, Tata McGraw Hill, fourth edition, 2010

**Course: Analog & Digital Electronics Laboratory**

| **Course Code** | MRAIPCC401-L | **Scheme of Evaluation** | PTW |
|---|---|---|---|
| **Teaching Plan** | 2-0-2-0 | **Term Work** | 50 |
| **Credits** | 1 | **Oral Exam** | 50 |

**Course Outcomes:**

At the end of the course, students will demonstrate the ability to:

1. Analyze and design various applications of Op-Amp.
2. Identify and characterize basic devices such as BJT and FET from their package information by referring to manufacturers' data sheets.
3. Design, simulate, built and debug complex sequential circuits based on an abstract functional specification.
4. Design, simulate, built and debug complex combinational circuits based on an abstract functional specification.

**Course Contents: Assignments / Practical based on**

Any Eight experiments / assignments from the list below (For Total Min. 24 Hours)

| **Expt. No.** | **Contents** | **Contact Hours** |
|---|---|---|
| **1** | Input and Output Characteristics of BJT in CE configuration. | 2 Hrs |
| **2** | Transfer and Drain Characteristics of MOSFET | 2 Hrs |
| **3** | Design and simulate LC and RC oscillators. | 4 Hrs |
| **4** | Build and test LC or RC oscillator. | 2 Hrs |
| **5** | Op-amp applications-I: Integrator, Differentiators, Comparator, Schmitt trigger. | 4 Hrs |
| **6** | Design different types of multivibrators using IC 555 | 2 Hrs |
| **7** | Simplification and implementation of a Boolean function using k -map technique e.g. code converter | 2 Hrs |
| **8** | Use of Multiplexers, Encoders, Demultiplexer and decoders for implementing logic. | 4 Hrs |
| **9** | Design and implementation of ripple and synchronous counters using JK and D FF and additional gates. | 4 Hrs |
| **10** | Design of MOD counter using ICs like 7490/93 (ripple) and 74192/193(synchronous) | 2 Hrs |

**Suggested learning resources:**

**Text Books:**

1. Behzad Razavi , “Fundamentals of Microelectronics” , Second Edition; Wiley, 2016.
2. Ramakant A Gaikwad, “Op-Amps and Linear Integrated Circuits”, PHI, 4th edition,2016

**Reference Books:**


1. Thomas L Floyd, “Electronic Devices”, 10th edition, Pearson, 2017
2. G.B.Clayton, “Operational Amplifiers”, International Edition, 2nd Edition,1979.
3. A. Anand Kumar, “Fundamentals of Digital circuits”, PHI, Fourth edition, 2016.
4. R.P. Jain, “Modern digital Electronics”, Tata McGraw Hill, fourth edition, 2010


**Course: Control Systems**

| **Course Code** | MRAIPCC402 | **Scheme of Evaluation** | MSE & ESE |
|---|---|---|---|
| **Teaching Plan** | 2-0-2-0 | **Mid Semester Exam** | 30 |
| **Credits** | 2 | **Teachers’ Assessment** | 10 |
| | | **End Sem Exam** | 60 |

**Course Outcomes:**

At the end of this course students will demonstrate the ability to:

1. Appreciate the role of the control system.
2. Analyze the mathematical model of the control system.
3. Analyze stability of the system.
4. Use bode plot for frequency domain analysis.
5. Analyze the control system in state space.

**Syllabus:**

| **Unit** | **Contents** | **Contact Hours** |
|---|---|---|
| **1** | **Introduction to Control System**<br>Introduction to control system block diagram. Importance of Control Systems. Components of control. Explanation with the help of the liquid level control system. Significance of actuators and sensors. Types of actuators, Types of sensors. Open loop control and closed loop control. Use of relays, switches and contactors for simple and sequential control systems.<br>**Control system representation**<br>Mathematical representation of simple mechanical, electrical, thermal, hydraulic systems. Block diagram representation and reduction. Signal flow graph. Transfer function of these systems. Pole zero concepts | 7 Hrs |
| **2** | **Time domain analysis**<br>Time response of first order, second order systems. Analysis of steady state error, Type of system and steady state error, Time response specifications. Effect of parameter variation on open loop and closed loop system response, sensitivity. Effect of feedback on system response, stability and disturbance | 5 Hrs |
| **3** | **Stability**<br>Concept of stability, Effect of pole zero location on stability, Routh- Hurwitz criterion. Root Locus method for analysis of gain margin, phase margin and stability.<br>**Control system analysis in frequency domain**<br>Concept of frequency domain behaviour, Bode Plot for analyzing systems in frequency domain. Frequency domain performance specifications. | 7 Hrs |

| | | |
|---|---|---|
| | Correlation between time domain and frequency domain specification. Nyquist Analysis | |
| 4 | **State Space Approach**<br>Representation of system in state space, Converting transfer function model into state space model.<br>Non uniqueness of state space model, Canonical representation, Eigenvalues, Solution of state equations, Concept of State feedback control, controllability, Observability. | 5 Hrs |

**Suggested learning resources:**

**Text Books:**


1. Nagrath & M. Gopal "Control System Engineering", Anshan, 2008
2. Norman S. Nice, "Control System Engineering", Wiley, 2008.


**Reference Books:**


1. Smarajit Ghosh, "Control Systems Theory & Applications", Pearson Education 2007
2. Katsuhiko Ogata," Modern Control Engineering", Prentice Hall, 2010.
3. Norman S. Nise, "Control System Engineering", Wiley, 2014


## Course: Control Systems Laboratory

| **Course Code** | MRAIPCC402-L | **Scheme of Evaluation** | PTW |
|---|---|---|---|
| **Teaching Plan** | 2-0-2-0 | **Term Work** | 50 |
| **Credits** | 1 | **Oral Exam** | 50 |

**Course Outcomes:**

At the end of this course students will demonstrate the ability to:

1. Develop the mathematical model of different components of linear feedback control system using simulation and experiments
2. Analyze the transient characteristics of different first order and second order systems using simulation and experiments
3. Determine the performance of system using root locus
4. Carry out the stability analysis of linear feedback control system using Bode plot and Nyquist plot
5. Analyze the different types of controllers like PI, PD, PID and tuning of these controllers using simulation and experiments

**Course Contents: Assignments / Practical based on**

Detailed Content :Any six experiments / assignments from the list below (For Total Min. 24 Hours)

| **Expt. No.** | **Contents** | **Contact Hours** |
|---|---|---|
| **1.** | To study input out characteristic of various control system components | 2 Hrs |
| **2** | To obtain step response and find time response specification of electrical system, hydraulic system, pneumatic system and thermal system. | 2 Hrs |
| **3** | To obtain transfer function and poles zeros of DC motor experimentally. | 2 Hrs |
| **4** | To obtain root locus experimentally. | 4 Hrs |

| | | |
|---|---|---|
| **5** | Use Matlab to study the effect of feedback gain on system response. | 2 Hrs |
| **6** | Use Matlab to study the effect of damping factor zeta on time control performance specifications. | 4 Hrs |
| **7** | Use Matlab to obtain root locus for a given system and find performance specifications there from. Study effect of addition of zero and pole on root locus | 4 Hrs |
| **8** | Use Matlab to get a bode plot and obtain gain margin and phase margin for various systems. | 2 Hrs |
| **9** | Use Matlab to obtain state space representation from transfer function, find Eigenvalues, Analyze controllability, observability and stability. | 4 Hrs |

**Suggested learning resources:**

**Text Books:**


1. Nagrath & M. Gopal "Control System Engineering", Anshan, 2008
2. Norman S. Nice, "Control System Engineering", Wiley, 2008.


**Reference Books:**


1. Smarajit Ghosh, "Control Systems Theory & Applications", Pearson Education 2007
2. Katsuhiko Ogata," Modern Control Engineering", Prentice Hall, 2010.
3. Norman S. Nise, "Control System Engineering", Wiley, 2014


## Course: Drives for Robot Systems

| **Course Code** | MRAIPCC403 | **Scheme of Evaluation** | MSE, PTE & ESE |
|---|---|---|---|
| **Teaching Plan** | 3-0-0-1 | **Mid Semester Exam** | 30 |
| **Credits** | 3 | **Teachers' Assessment** | 20 |
| | | **End Sem Exam** | 50 |

**Course outcomes:**

At the end of this course students will demonstrate the ability to:
1. Analyze DC drive, Induction and Synchronous Motors Drives.
2. Evaluate the steady state behavior and basic operating characteristics of A.C Machine.
3. Understand the basics of electric drives and fundamentals of drive dynamics.
4. Demonstrate analytical skills to assess machine performance in steady state.
5. Analyze the integration of the hydraulic drives & pneumatic drives in robotic systems

**Syllabus:**

| Unit | Contents | Lecture |
|---|---|---|
| **1** | **D.C. Motors & Other Motors**<br>Principles of working, Significance of back emf, Torque Equation, Types, Characteristics and Selection of DC Motors, Starting of DC Motors, Speed Control, Losses and Efficiency, Condition for Maximum Efficiency, Braking of DC Motors, Effect of saturation and armature reaction on losses; Applications, Permanent Magnet DC Motors, Type and Routine tests.<br>PMAC and BLDC motor drives, Stepper motor drives, switched reluctance motor drives. | 6 Hrs |
| **2** | **Synchronous Motors and Asynchronous Motor** | 6 Hrs |

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|---|---|---|
| | Construction, types, armature reaction, circuit model of synchronous machine, determination of synchronous reactance, phasor diagram, power angle characteristics, parallel operation of synchronous generators, synchronizing to infinite bus bars, two axis theory, synchronous motor operation, dynamics, modeling of synchronous machine, PM synchronous machines.<br>Types of induction motor, flux and mmf waves, development of circuit model, power across air gap, torque and power output, starting methods, speed control, induction generator, induction machine dynamics, high efficiency induction motors, Single phase IM, Modeling of induction machine. | |
| **3** | **Electric Drives, Dynamics and Control**<br>Definition, Advantages of electrical drives, Components of Electric drive system, Selection Factors, speed control and drive classifications, Motor-Load Dynamics, Speed Torque conventions and multi quadrant operation, Equivalent values of drive parameters. Load Torque Components, Nature and classification of Load Torques, Constant Torque and Constant Power operation of a Drive, Steady state stability, Load epilation and selection motors. | 6 Hrs |
| **4** | **Performance & Control of DC Motor**<br>Dc motors and their performance starting, transient analysis, speed control, ward Leonard drives, Controlled rectifier fed drives, full controlled 3 phase rectifier control of dc separately excited motor], multi-quadrant operation, Chopper controlled drives Closed loop speed control of DC motor. | 6 Hrs |
| **5** | **Performance & Control of Induction and Synchronous Motor Drives**<br>Induction motor analysis, starting and speed control methods- voltage and frequency control, current control, closed loop control of induction motor drives, rotor resistance control, Slip power recovery – Static Kramer and Scherbius Drive, Single phase induction motor starting, braking and speed control. Synchronous motor operation with fixed frequency, variable speed drives. | 6 Hrs |
| **6** | **Hydraulic and Pneumatic Drives**<br>Overview of hydraulic and pneumatic drives in robot applications, Working principles and control of hydraulic and pneumatic drives, Advantages, limitations, and applications of hydraulic and pneumatic drives in robots, Advanced Drive Systems - Introduction to advanced drive systems (linear drives, magnetic drives, etc.), Emerging trends and technologies in robot drive systems, Integration of advanced drive systems with robot applications | 6 Hrs |

**Suggested learning resources:**

**Text Books:**

1. D. P. Kothari, I. J. Nagrath, “Electric Machines”, Tata McGraw Hill Publication, Fourth edition, reprint 2012.
2. A.E. Fitzgerald, Charles Kingsley Jr., Stephen D. Umans, “Electric Machinery”, Tata McGraw Hill Publication, sixth edition, 2002.

**Reference Books:**

1. M. G. Say, “Alternating current machines”, fifth edition, E.L.B.S. Publication, 1987.
2. F. Puchstein, T.C. Lloyd, A.G. Conrad, “Alternating current machines”, John Wiley and

Sons, New York 1954.
3. P. C. Sen, "Principles of Electric Machines and Power Electronics", John Wiley and Sons Publication, second edition 1997.
4. M. H. Rashid,"Power Electronics-Circuits, devices & Applications", 3rd Ed, PHI Pub. 2004.
5. B. K. Bose, "Modern Power Electronics & AC Drives", Pearson Education, Asia, 2003
6. G. K. Dubey, "Fundamentals of Electrical Drives", Second edition (sixth reprint), Narosa Publishing house, 2001

## Course: Standards & Ethics for Robot Applications

| Course Code | MRAIPCC404 | Scheme of Evaluation | MSE & ESE |
|---|---|---|---|
| Teaching Plan | 2-0-0-2 | Mid Semester Exam | CIE: 100 |
| Credits | 2 | End Sem Exam | |

**Course Outcomes :**
Students who successfully complete this course will have demonstrated an ability to:

1. Study the fundamental concepts and terminologies related to standards and ethics in the context of robot applications.
2. Identify the key industry standards and regulatory frameworks governing robot design, safety, and performance.
3. Analyze the ethical challenges and implications associated with the development and use of robots.
4. Evaluate the societal impact of robots and assess their ethical implications on various stakeholders.
5. Comprehend the legal and liability considerations related to robots and their applications.

**Syllabus:**

| Unit | Contents | Lecture |
|---|---|---|
| **1** | **Introduction**<br>Introduction to Standards and Ethics in Robotics, Introduction to the field of robotics and its ethical dimensions, Overview of relevant industry standards and regulatory frameworks, The ISO (International Organization for Standardization) standard for robot safety is ISO 10218 - Robots for Industrial Environments - Safety Requirements | 6 Hrs |
| **2** | **Robot Safety Standards**<br>Overview of safety standards for robots in various environments (industrial, medical, etc.), Risk assessment and mitigation strategies for robot applications, Ethical considerations in ensuring robot safety Robot | 6 Hrs |
| **3** | **Ethical Challenges in Robot Applications**<br>Ethical dilemmas in robot design, deployment, and use, Privacy and data protection considerations in robot applications, Ethical implications of autonomous decision-making by robots. Societal Impact Of Robots: Understanding the social and economic implications of robots, Ethical considerations in robot automation and job displacement, Robot ethics and the digital divide. | 6 Hrs |

| | | | |
|---|---|---|---|
| **4** | **Standards, Regulation, and the Future**<br>Standards and Regulatory Landscape: Examining existing and emerging standards for robot safety and responsible development (e.g., ISO standards, national regulations).<br>The Future of Robot Ethics: Exploring emerging trends in robotics and their ethical implications (e.g., artificial general intelligence, job displacement).<br>Responsible Development and Deployment: Developing a framework for promoting ethical and responsible robot design, use, and governance. | 6 Hrs |

**Suggested learning resources:**

**Textbook:**

1. Peter Corke "Robotics, Vision and Control: Fundamental Algorithms in MATLAB" Springer
2. Patrick Lin, Keith Abney, and Ryan Jenkins , "Robot Ethics 2.0: From Autonomous Cars to Artificial Intelligence" Oxford University Press
3. Patrick Lin, Keith Abney, and Ryan Jenkins , "Robot Ethics 2.0: From Autonomous Cars to Artificial Intelligence" Oxford University Press

**Reference Books:**

1. Ryan Calo, A. Michael Froomkin, and Ian Kerr (Eds.),"Robot Law" Edward Elgar publishing
2. Joseph E. Aoun, "Robot-Proof: Higher Education in the Age of Artificial Intelligence" The MIT Press
3. Joseph Migga Kizza, "Ethical and Social Issues in the Information Age" Springer
4. Joe Jones, Daniel Roth, and Charles E. Irwin, "Robot Programming: A Practical Guide to Behavior-Based Robotics" A K Peters/CRC Press
5. Brigette Tasha Hyacinth, "The Future of Leadership: Rise of Automation, Robotics, and Artificial Intelligence" Motivational Press
6. ISO 10218-1:2011 Robots and robotic devices - Safety requirements for industrial robots

**Course: Numerical Methods & Programming Language**

| **Course Code** | MRAIBSC407 | **Scheme of Evaluation** | MSE & ESE |
|---|---|---|---|
| **Teaching Plan** | 1-0-2-1 | **Mid Semester Exam** | CIE: 100 |
| **Credits** | 1 | **End Sem Exam** | |

**Course Outcome:**

Students who successfully complete this course will have demonstrated an ability to:

1. Understand the basic principles of numerical methods and their role in scientific and engineering computations.
2. Apply numerical techniques to solve mathematical problems, including root finding, interpolation, differentiation, integration, and linear systems.
3. Implement numerical algorithms using a programming language to solve computational problems efficiently.
4. Analyze the accuracy, stability, and convergence of numerical methods.
5. Apply numerical methods and programming skills to solve real-world engineering and scientific problems.

**Syllabus:**

| **Unit** | **Contents** | **Lecture** |
|---|---|---|
| **1** | **Numerical Methods and Programming** | 6 Hrs |

| | | |
|---|---|---|
| | Introduction to a programming language for scientific computing, Basics of programming: variables, control structures, functions, and data types.<br>Root Finding Methods Bisection method, Newton-Raphson method, Secant method, Comparison and analysis of root finding methods<br>**Numerical Differentiation and Integration**<br>Finite difference approximations, Numerical integration methods (Trapezoidal rule, Simpson's rule), Romberg integration, Error estimation and adaptive integration | |
| **2** | **Linear Systems of Equations**<br>Gaussian elimination, Iterative methods (Jacobi, Gauss-Seidel, and SOR), Matrix factorizations and sparse systems,<br>**Numerical Solutions of Ordinary Differential Equations**<br>Euler's method, Runge-Kutta methods, Multistep methods (Adams-Bashforth, Adams-Moulton), Stability analysis and error control<br>**Numerical Linear Algebra**<br>Matrix computations (Eigen-values, singular value decomposition), Iterative methods for large linear systems, preconditioning techniques, | 6 Hrs |

**Suggested learning resources:**

**Textbooks:**


1. Advanced Engineering Mathematics (10th edition ) by Erwin Kreyszig, Wiley eastern Ltd.
2. George Simmons, “Differential Equations with Applications and Historical notes”, Tata Mc- Graw Hill publishing company Ltd, New Delhi, 2006.
3. C.R. Wylie, “ Advanced Engineering Mathematics” , McGraw Hill Publications, New Delhi, 2017.


**Reference Books**


1. Gerald, C. F. and Wheatly, P. O.," Applied Numerical Analysis", 6th Edition, Wesley.
2. Jain, M. K., Iyengar, S. R. K. and Jain, R. K., "Numerical Methods for Scientific and Engineering Computation", New Age Pvt. Pub, New Delhi.
3. Conte, S. D. and De Boor, C., "Elementary Numerical Analysis", Mc Graw Hill Publisher.


**Course: Numerical Methods & Programming Language Laboratory**

| **Course Code** | MRAIBSC407-L | **Scheme of Evaluation** | TW & OE |
|---|---|---|---|
| **Teaching Plan** | 1-0-2-2 | **Term Work** | 50 |
| **Credits** | 1 | **Oral Exam** | 50 |

**Course Contents: Assignments / Practical based on**

| Unit | Contents | Contact Hours |
|---|---|---|
| **1** | **Interpolation and Curve Fitting**<br>Polynomial interpolation (Lagrange and Newton), Least squares approximation, Spline interpolation, Error analysis and selection of interpolation methods, | 3 Hrs |
| **2** | **Optimization Methods** | 3 Hrs |

| | | |
|---|---|---|
| | Unconstrained optimization (gradient-based and gradient-free methods), Constrained optimization (linear and nonlinear programming), Introduction to optimization libraries and tools | |
| **3** | **Numerical Solutions of Partial Differential Equations**<br>Finite difference methods, Finite element methods, Introduction to numerical methods for heat and wave equations, | 3 Hrs |
| **4** | **Introduction to Numerical Probability and Statistics**<br>Random number generation, Monte Carlo methods, Statistical analysis of numerical data | 3 Hrs |
| **5** | **Introduction to Data Visualization and Plotting**<br>Visualization libraries and tools, Data plotting and visualization techniques, Exploratory data analysis and presentation | 3 Hrs |
| **6** | **Numerical Methods in Practice and Project Work**<br>Application of numerical methods to real-world problems, Project work: implementation of a numerical algorithm, analysis of results, and presentation | 3 Hrs |

**Suggested learning resources:**

**Textbooks:**


1. Peter V. O' Neil, "Advanced Engineering Mathematics", (7th edition) , Thomson. Brooks / Cole, Singapore,1991.
2. Michael D. Greenberg, "Advanced Engineering Mathematics", (2nd edition), Pearson Education,1998.


**Reference Books**


1. Krishnamurthy, E. V. & Sen, S. K., "Applied Numerical Analysis", East West Publication.


**Open Elective**

**Entrepreneurship**

**Environmental Science**

**Summer Internship-after Sem IV-Exam in Sem V**

# Syllabus for Exit After SY -- Additional Credits for Diploma

**Course: Robotic Simulation Laboratory**

| Course Code | MRAIVSEC4E1-L | Scheme of Evaluation | MSE & ESE |
|---|---|---|---|
| **Teaching Plan** | 0-1-2-0 | **Term Work** | 50 |
| **Credits** | 1 | **Oral Exam** | 50 |

**Course Contents: Assignments / Practical based on**

| Expt. No. | Contents | Contact Hours |
|---|---|---|
| **1** | Physics simulations of Robots with Gazebo, Mujoco and Pybullet C++/Python APIs | 4 Hrs |
| **2** | Simulation of 6-dof manipulator in ROS | 4 Hrs |
| **3** | Dynamic model development and simulation of simple mechanical systems using Matlab and Mathematical. | 4 Hrs |
| **4** | Numerical simulation of simple mechanical systems. | 4 Hrs |
| **5** | Stability analysis of simple mechanical systems using linear system theory namely root locus and Bode plot | 4 Hrs |
| **6** | State space model development and dynamic simulation using Simulink | 4 Hrs |

**Reference Books:**


1. Corke, Peter I. Robotics, vision and control : fundamental algorithms in Matlab. 1st ed. New York: Springer, 2011. ISBN 978- 3-642-20143-1.
2. Devendra K Chaturvedi, ―Modelling and Simulation of Systems using MATLAB and Simulink , CRC press, 2010
3. Learning ROS for Robotics Programming, Aaron Martinez, Enrique Fernandez, PACKT publishing, 2013
4. Programming Robots with ROS, Morgan Quigley, Brian Gerkey, & William D Smart, SPD Shroff Publishers and Distributors Pvt Ltd., 2016
5. Mastering ROS for Robotics Programming: Design, build, and simulate complex robots using the Robot Operating System, Lentin Joseph, PACKT publishing, 2015


**Course: Aerial Robotics Programming Laboratory**

| | | | |
|---|---|---|---|
| **Course Code** | MRAIVSEC4E2-L | **Scheme of Evaluation** | MSE & ESE |
| **Teaching Plan** | 0-1-2-2 | **Term Work** | 50 |
| **Credits** | 1 | **Oral Exam** | 50 |

**Course Contents: Assignments / Practical based on**

Detailed Content :Any six experiments / assignments from the list below (For Total Min. 24 Hours)

| Expt. No. | Contents | Contact Hours |
|---|---|---|
| **1** | Introduction to Drone Technology Lab<br>Overview of the lab equipment and safety protocols<br>Introduction to basic drone components (frame, motors, flight controller)<br>Familiarization with tools and software used in the lab | 4 Hrs |
| **2** | Drone Assembly and Disassembly<br>Step-by-step assembly of a drone kit<br>Understanding the purpose and function of each component<br>Disassembly of the drone for maintenance and troubleshooting | 4 Hrs |

| | | |
|---|---|---|
| **3** | Flight Controller Configuration<br>Introduction to flight controller software (e.g., Betaflight, Ardupilot)<br>Basic configuration and calibration of the flight controller<br>Setting up flight modes and fail safes | 4 Hrs |
| **4** | Basic Flight Maneuvers<br>Practice basic flight maneuvers such as take-off, landing, and hovering<br>Introduction to different flight modes (e.g., stabilized, acro)<br>Understanding control inputs (pitch, roll, yaw) | 4 Hrs |
| **5** | Autonomous Flight<br>Introduction to autonomous flight modes (e.g., GPS-assisted flight)<br>Planning and executing autonomous missions using mission planning software, Understanding geofencing and no-fly zones | 4 Hrs |
| **6** | Payload Integration<br>Introduction to different types of payloads (e.g., cameras, sensors)<br>Mounting and integrating payloads onto the drone, Testing payload functionality in flight | 4 Hrs |
| **7** | Advanced Flight Maneuvers<br>Practice advanced flight maneuvers such as banked turns, figure-eight patterns, Introduction to acrobatic maneuvers (flips, rolls), Flight proficiency assessment | 4 Hrs |
| **8** | Drone Maintenance and Repair<br>Routine maintenance tasks (cleaning, propeller replacement, battery care)<br>Diagnosing and troubleshooting common issues (motor failure, GPS signal loss), Repairing and replacing damaged components | 4 Hrs |
| **9** | Data Collection and Analysis<br>Introduction to data collection techniques (e.g., aerial photography, mapping), Processing and analyzing data collected by drones<br>Applications of drone-collected data in various industries | 4 Hrs |

**Reference Books:**


1. Build Your Own Drone Manual: The practical guide to safely building, operating and maintaining an Unmanned Aerial Vehicle (UAV), by Alex Eliott, 2016, Publisher: Haynes Publishing
2. Introduction to UAV Systems, by Paul Fahlstrom and Thomas Gleason, 2012, CreateSpace Independent Publishing Platform
3. Quadcopter and Drone Photography: How to Bring Your Photography or Videography to the Next Level, by Eric Cheng, 2014, Peachpit Press
4. DIY Drones for the Evil Genius: Design, Build, and Customize Your Own Drones, by Ian Cinnamon and Romi Kadri, 2016, McGraw-Hill Education TAB
5. Drone Technology and Applications, edited by Changdon Kee and Hesham ElSayed, 2019, Wiley-IEEE Press
6. Small Unmanned Aircraft: Theory and Practice, by Randal W. Beard and Timothy W. McLain, 2012, Princeton University Press
7. Drones: Mastering Flight Techniques, by Brian Halliday, 2016, Wiley

8. Aerial Photography and Videography Using Drones, by Eric Cheng, 2015, Peachpit Press
9. Drone Technology: Types, Operations, and Applications, by Kevin Downing, 2020, Nova Science Publishers
10. Drone Operator's Handbook, by Kevin Jenkins, 2017, Independently published.

**Course: Control System Laboratory**

| **Course Code** | MRAIVSEC4E3-L | **Scheme of Evaluation** | MSE & ESE |
|---|---|---|---|
| **Teaching Plan** | 0-1-2-0 | **Term Work** | 50 |
| **Credits** | 1 | **Oral Exam** | 50 |

**Course Contents: Assignments / Practical based on**

Detailed Content (Any Eight experiments / assignments from the list below)

| Expt. No. | Contents | Contact Hours |
|---|---|---|
| **1** | Programming of HCS12 with Code warrior for Interrupts, Clock Functions | 4 Hrs |
| **2** | TIM, RTI, SPI, LCD interfacing, | 2 Hrs |
| **3** | Use of JTAG and Hardware Debuggers, Interfacing Keypad | 4 Hrs |
| **4** | ADC, DAC, LCD, Real Time Clock | 4 Hrs |
| **5** | Temperature Sensors with I2C and SPI bus | 2 Hrs |
| **6** | Interface 7 segment LED to 8051 to generate flashing action | 2 Hrs |
| **7** | Interface Analog to Digital converter to 8051 and display the result on LCD display | 4 Hrs |
| **8** | Interface Digital to Analog converter to 8051 and view the output on CRO Interface stepper motor to 8051 it through given number of steps | 4 Hrs |
| **9** | Perform serial communication using 8051 | 2 Hrs |
| **10** | Decentralized motion control and Centralized motion control | 4 Hrs |
| **11** | Feed-forward compensation, Force control, Visual surveying | 4 Hrs |
| **12** | Linear controller (P,PI,PD and PID) design for simple position control of mechanical systems. | 4 Hrs |

**Reference Books:**

1. W. Bolton, Mechatronics - Electronic Control systems in Mechanical and Electrical Engineering-, 2nd Edition, Addison Wesley Longman Ltd., 1999.
2. Brian Morris, Automated Manufacturing Systems - Actuators, Controls, Sensors and Robotics, Mc Graw Hill International Edition, 1995.
3. I.J. Nagarath and M. Gopal, Control Systems Engineering, New Age International (P) Ltd.
4. M. Gopal, Digital Control and State Variable Methods, Tata Mc Graw-Hill Companies, 1997.

## Course: Mini Project

| Course Code | MRAIVSEC6E4 | Scheme of Evaluation | MSE & ESE |
|---|---|---|---|
| **Teaching Plan** | **0-2-0-0** | **Term Work** | 50 |
| **Credits** | 2 | **Oral Exam** | 50 |

**Course Outcomes:**

Students who successfully complete this course will have an ability to:

1. Conceive a problem statement either from rigorous literature survey or from the requirements raised from need analysis.
2. Design, implement and test the prototype/algorithm in order to solve the conceived problem.
3. Write a comprehensive report on mini project work.

**Guidelines:**

1. The mini-project is a team activity having 3-4 students in a team. Mini projects should include mainly Mechanical Engineering but can be multi disciplinary too.
2. The mini project may be a complete hardware or a combination of hardware and software. The software part in the mini project should be less than 50% of the total work.
3. Mini Project should cater to a small system required in laboratory or real life.
4. It should encompass components, devices etc. with which functional familiarity is introduced.
5. After interactions with course coordinator and based on comprehensive literature survey/ need analysis, the student shall identify the title and define the aim and objectives of the mini-project.
6. Students are expected to detail out specifications, methodology, resources required, critical issues involved in design and implementation and submit the proposal within the first week of the semester.
7. The student is expected to exert on design, development and testing of the proposed work as per the schedule.
8. Completed mini project and documentation in the form of mini project report is to be submitted at the end of semester.

**Open Elective-II**

**Multidisciplinary Minor - I**

**Numerical Methods & Programming Language**

**Principles of Economics**

**Environmental Studies**

**[Note- Above subject’s syllabus will be from respective department]**

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# Semester -V

**Course: Artificial Intelligence & Machine Learning**

| Course Code | MRAIPCC502 | Scheme of Evaluation | MSE & ESE |
|---|---|---|---|
| Teaching Plan | 3-0-2-4 | Mid Semester Exam | 30 |
| Credits | 3 | Teachers' Assessment | 20 |
| | | End Sem Exam | 50 |

**Course Outcomes:**

Students who successfully complete this course will have demonstrated an ability to:

1. Solve problems using heuristic search (e.g., A*).
2. Implement learning and planning algorithms (e.g., goal stacks).
3. Design neural networks with backpropagation for complex tasks.
4. Classify data using supervised learning (K-NN, SVM).
5. Evaluate models with metrics and error correction.

**Syllabus:**

| Unit | Contents | Lecture |
|---|---|---|
| **1** | **Heuristic search techniques**<br>Heuristic search, Hill Climbing, Best first search, mean and end analysis, Constraint Satisfaction, A* and AO* Algorithm | 6 Hrs |
| **2** | **Learning & Planning**<br>What is Learning, Types of Learning (Rote, Direct instruction Analogy, Induction, Deduction), Planning: Block world, strips, Implementation using goal stack, Non linear planning with goal stacks, Hierarchical planning, Least commitment strategy. | 6 Hrs |
| **3** | **Neural Networks and Expert systems**<br>Neurons and biological motivation. Linear threshold units. Perceptrons: representational limitation and gradient descent training. Multilayer networks and backpropagation, Hidden layers and constructing intermediate, distributed representations, Overfitting, learning network structure, two case studies on expert systems. | 6 Hrs |
| **4** | **Introduction to Machine Learning**<br>Introduction to Machine Learning, Learning Paradigms, PAC learning, Basics of Probability, Version Spaces, Classification of Machine learning problem, Supervised, unsupervised, Reinforcement learning. Classifiers K-NN classifier, Logistic regression, Perceptron, Single layer & Multi-layer, Support Vector Machines, Linear & Non-linear. | 6 Hrs |
| **5** | **Evaluation Metrics and ensemble learning**<br>ROC Curves, Evaluation Metrics, Significance tests, Error correction in Perceptrons- Bagging and Boosting (Random forests, Adaboost, XG boost inclusive), Machine learning process in practice | 6 Hrs |
| **6** | **Hypothesis Design**<br>Types of variables, Types of measurement scales, Constructing the Hypothesis, Null hypothesis, Alternative Hypothesis. Hypothesis testing, type 1 error, Type 2 error, Confidence of Interval. | 6 Hrs |

**Suggested learning resources:**

**Textbooks:**


1. Ethem Alpaydin,"Introduction to Machine Learning‖, MIT Press, Prentice Hall of India, Third Edition 2014.


**Reference Books:**

1. Mehryar Mohri, Afshin Rostamizadeh, Ameet Talwalkar "Foundations of Machine Learning”, MIT Press, 2012.
2. Tom Mitchell, Machine Learning‖, McGraw Hill, 3rd Edition,1997.
3. Charu C. Aggarwal, Data Classification Algorithms and Applications‖, CRC Press, 2014.
4. Christopher M. Bishop, Pattern Recognition and Machine Learning‖, Springer Edition. 2011.

## Course: Artificial Intelligence & Machine Learning Laboratory

| Course Code | MRAIPCC502-L | Scheme of Evaluation | MSE & ESE |
|---|---|---|---|
| **Teaching Plan** | **3-0-2-4** | **Term Work** | 50 |
| **Credits** | **1** | **Oral Exam** | 50 |

**Course Outcomes:**

Students who successfully complete this course will have an ability to:

1. Develop an Explanation of what is involved in learning models from data.
2. Implement a wide variety of learning algorithms.
3. Apply principles and algorithms to evaluate models generated from data.
4. Apply the algorithms to a real-world problem

**Course Contents: Assignments / Practical based on:**

| Expt. No. | Contents | Contact Hours |
|---|---|---|
| **1** | Implement A* algorithm . | 4 Hrs |
| **2** | Implement AO* algorithm | 4 Hrs |
| **3** | Implementation of other Searching algorithms. | 4 Hrs |
| **4** | Implementation of Min/MAX search procedure for game Playing | 4 Hrs |
| **5** | Implementation of variants of Min/ Max search procedure. | 4 Hrs |
| **6** | Implementation of a mini Project using the concepts studied in the AI course. | 4 Hrs |

**Suggested learning resources:**

**Textbooks:**

1. Artificial Intelligence: A Modern Approach by Peter Norvig and Stuart J. Russell
2. Artificial Intelligence for Dummies by John Paul Mueller and Luca Massaron

**Reference Books:**

1. Keith Frankish and William M. Ramsey (Eds.), “The Cambridge Handbook of Artificial Intelligence” Cambridge University Press.
2. Brigette Tasha Hyacinth, “The Future of Leadership: Rise of Automation, Robotics, and Artificial Intelligence” Motivational Press

## Course: Fundamentals of Robot Manipulators

| Course Code | MRAIPCC503 | Scheme of Evaluation | MSE & ESE |
|---|---|---|---|
| Teaching Plan | 2-0-0-0 | Mid Semester Exam | 30 |
| Credits | 2 | Teachers' Assessment | 20 |
| | | End Sem Exam | 50 |

**Course Outcomes:**

Students who successfully complete this course will have demonstrated an ability to:

1. Understand robot kinematics and dynamics principles.
2. Gain proficiency in kinematic and dynamic 39odelling of robot manipulators.
3. Design and implement control strategies for robot manipulators.
4. Implement skills in planning and executing manipulation tasks, including trajectory planning and obstacle avoidance.
5. Apply robotic concepts to real-world scenarios in various domains.

**Syllabus:**

| Unit | Contents | Lecture |
|---|---|---|
| 1 | **Introduction to Robotics**<br>Overview of Robotics: Definition, history, and evolution.<br>Classification of Robots: Based on kinematics, functionality, application, etc., Robot Components: Sensors, actuators, end-effectors, controllers, etc. Robot Kinematics: Forward and inverse kinematics, Denavit-Hartenberg parameters(Classical & Modern), Robot Dynamics: Newton-Euler equations, Lagrangian formulation. | 6 Hrs |
| 2 | **Robot Manipulator Kinematics**<br>Introduction to Manipulator Kinematics: Degrees of freedom, workspace, redundancy.<br>Forward Kinematics: Homogeneous transformations, DH convention, transformation matrices. Inverse Kinematics: Analytical and numerical methods, Jacobian matrix, singularity analysis.Velocity Kinematics: End-effector velocities, Jacobian matrix, velocity control. | 6 Hrs |
| 3 | **Robot Manipulator Dynamics**<br>Introduction to Manipulator Dynamics: Newton-Euler equations, Euler-Lagrange equations. Lagrangian Formulation: Energy-based approach to derive robot dynamics.<br>Manipulator Dynamics: Manipulator inertia matrix, Coriolis and centrifugal forces, gravity forces.<br>Control of Robot Manipulators: PD control, PID control, computed torque control. | 6 Hrs |
| 4 | **Advanced Topics in Robot Manipulation**<br>Trajectory Planning: Path planning, motion planning, obstacle avoidance.<br>Force Control: Compliance control, force/torque sensing, impedance control.<br>Robotic Manipulation: Grasping and manipulation, force-closure, dexterity.<br>Applications of Robot Manipulators: Industrial robots, service robots, medical robots, etc. | 6 Hrs |

**Suggested learning resources:**

**Textbooks:**

1. Introduction to Robotics: Mechanics and Control" by John J. Craig.

**Reference Books:**

1. "Robotics: Modelling, Planning and Control" by Bruno Siciliano, Lorenzo Sciavicco, Luigi Villani, and Giuseppe Oriolo
2. "Robot Dynamics and Control" by Mark W. Spong, Seth Hutchinson, and M. Vidyasagar –
3. "Modern Robotics: Mechanics, Planning, and Control" by Kevin M. Lynch and Frank C. Park
4. "Robot Manipulator Control: Theory and Practice" by Frank L. Lewis, Darren M. Dawson, and Chaouki T. Abdallah

## Course: Signals & Systems

| **Course Code** | MRAIPCC504 | **Scheme of Evaluation** | MSE & ESE |
|---|---|---|---|
| **Teaching Plan** | **2-0-2-2** | **Mid Semester Exam** | 30 |
| **Credits** | **2** | **Teachers' Assessment** | 20 |
| | | **End Sem Exam** | 50 |

**Course Outcomes:**

Students who successfully complete this course will have demonstrated an ability to:

1. Understand signals & systems fundamentals and applications.
2. Analyze signals & systems using Fourier Transforms, Laplace Transforms, z-Transforms.
3. Apply convolution to analyze LTI systems.
4. Design simple filters and understand sampling concepts.
5. Relate concepts to communication, filtering, control systems.

**Syllabus:**

| Unit | Contents | Lecture |
|---|---|---|
| **1** | **Introduction to Signals and Systems**<br>Signals and systems as seen in everyday life, and in various branches of engineering and science. Signal properties: periodicity, absolute integrability, determinism and stochastic character. Some special signals of importance: the unit step, the unit impulse, the sinusoid, the complex exponential, some special time-limited signals; continuous and discrete time signals, continuous and discrete amplitude signals. Classification of systems - Static and dynamic, Linear and nonlinear, Time-variant and time-invariant, Causal and non-causal, Stable and unstable, Impulse response and step response of systems. System properties: linearity: additivity and homogeneity, shift-invariance, causality, stability, realizability. Examples. | 5 Hrs |
| **2** | **Behavior of continuous and discrete-time LTI systems**<br>Impulse response and step response, convolution, input-output behavior with aperiodic convergent inputs, cascade interconnections. Characterization of causality and stability of LTI systems. System representation through differential equations and difference equations. State-space Representation of systems. State-Space Analysis, Multi-input, multi-output representation. | 5 Hrs |

| | | |
|---|---|---|
| | State Transition Matrix and its Role. Periodic inputs to an LTI system, the notion of a frequency response and its relation to the impulse response. | |
| **3** | **System Analysis of Fourier Transforms**<br>Fourier series representation of periodic signals, Waveform Symmetries, Calculation of Fourier Coefficients. Fourier Transform, convolution/multiplication and their effect in the frequency domain, magnitude and phase response, Fourier domain duality., Continuous-time Fourier transform (CTFT), The Discrete- Time Fourier Transform (DTFT) and the Discrete Fourier Transform (DFT). Parseval's Theorem, Inverse Fourier Transform<br>**System Analysis of Laplace Transform**<br>Relation between Laplace and Fourier transforms, Review of the Laplace Transform for continuous time signals and systems, system functions, poles and zeros of system functions and signals, Laplace domain analysis, Inverse Laplace transform, solution to differential equations and system behavior. | 7 Hrs |
| **4** | **System Analysis of z- Transforms**<br>The z-Transform for discrete time signals and systems, system functions, poles and zeros of systems and sequences, z-domain analysis, s-plane to z-plane mapping, Inverse z-transform, Solution to difference equations using z-transform, Region of convergence, Stability analysis<br>**Sampling and Reconstruction**<br>The Sampling Theorem and its implications. Spectra of sampled signals. Reconstruction: ideal interpolator, zero-order hold, first-order hold. Aliasing and its effects. Relation between continuous and discrete time systems. Introduction to the applications of signal and system theory: modulation for communication, filtering, feedback control systems. | 7 Hrs |

**Suggested learning resources:**

**Textbooks:**


1. Michael J. Robert, "Introduction to Signals and Systems", TMH, Second ed., 2003
2. Tarun Kumar Rawat "Signals and Systems", Oxford University Press, first edition 2010
3. Alan V Oppenhein, Alan S Wiilsky, "Signals and systems" PHI, Second ed. 2009
4. J. G. Proakis and D. G. Manolakis, "Digital Signal Processing: Principles, Algorithms, and Applications", Pearson, 2006.


**Reference Books:**


1. A. V. Oppenheim, A. S. Willsky and S. H. Nawab, " Signals and systems", Prentice Hall India, 1997.
2. S. Haykin and B. V. Veen, " Signals and Systems", John Wiley and Sons, 2007.
3. A. V. Oppenheim and R. W. Schafer, " Discrete-Time Signal Processing", Prentice Hall, 2009.


## Course: Signals & Systems Laboratory

| **Course Code** | MRAIPCC504-L | **Scheme of Evaluation** | MSE & ESE |
|---|---|---|---|

| Teaching Plan | 2-0-2-2 | Term Work | 50 |
|---|---|---|---|
| **Credits** | **1** | **Oral Exam** | 50 |

**Course Outcomes:**

Students who successfully complete this course will have an ability to:

1. Understand the concepts of 'Signals and Systems' by experimentation.
2. Develop based knowledge on theoretical concepts learned.

**Course Contents: Assignments / Practical based on:**

Any Eight : List of experiments to be performed on Matlab

| Expt. No. | Contents | Contact Hours |
|---|---|---|
| **1** | To find convolution of two sequences | 2Hrs |
| **2** | To check linearity property of Fourier transform | 2Hrs |
| **3** | To check whether the system y[n] = cos(x[n]) is time varying or time-invariant | 4Hrs |
| **4** | To find Fourier transform of given sequence | 2Hrs |
| **5** | To plot unit delta sequence, unit step sequence & unit ramp sequence | 4Hrs |
| **6** | To study convolution property of Fourier transform | 2Hrs |
| **7** | To study Discrete Fourier transform | 4Hrs |
| **8** | To study inverse Discrete Fourier transform | 2Hrs |
| **9** | To study time-shift property of Fourier transform | 2Hrs |

**Suggested learning resources:**

**Textbooks:**

1. H. P. Hsu, "Signals and systems", Schaum's series, McGraw Hill Education, 2010.
2. M. J. Robert "Fundamentals of Signals and Systems", McGraw Hill Education, 2007.

**Reference Books**

1. B. P. Lathi, "Linear Systems and Signals", Oxford University Press, 2009.

## Course: Mobile and Micro Robotics (PEC-I)

| Course Code | MRAIPEC505-R | Scheme of Evaluation | MSE TA& ESE |
|---|---|---|---|
| **Teaching Plan** | **3-0-0-0** | **Mid Semester Exam** | 30 |
| **Credits** | 3 | **Teachers' Assessment** | 20 |
| | | **End Sem Exam** | 50 |

**Course Outcomes:**

Students who successfully complete this course will have an ability to:

1. Grasp mobile robot fundamentals: Tasks, types, environments, challenges, and applications.
2. Analyze mobile robot locomotion: Kinematics and dynamics of wheeled, legged, aerial, and aquatic robots.

3. Navigate and localize mobile robots: Sensor applications, odometry, mapping, and Kalman filtering for positioning.
4. Control mobile robot motion: Model-based and motion control design principles.
5. Explore advanced topics: Microrobotics, mobile manipulators, and cooperative robots.

**Syllabus:**

| Unit | Contents | Lecture |
|---|---|---|
| **1** | **Introduction to Mobile Robots:**<br>Tasks of mobile robots, robot_s manufacturers, type of obstacles and challenges, tele-robotics, philosophy of robotics, service robotics, types of environment representation. Ground Robots: Wheeled and Legged Robots, Aerial Robots, Underwater Robots and Surface Robots. | 6 Hrs |
| **2** | **Kinematics and Dynamics of Wheeled Mobile Robots**:<br>Two, three, four - wheeled robots, omni-directional and meccanum wheeled robots. Sensors for localization: magnetic and optic position sensor, gyroscope, accelerometer, magnetic compass, inclinometer, GNSS and Sensors for navigation: tactile and proximity sensors, ultrasound rangefinder, laser scanner, infrared rangefinder, visual system | 6 Hrs |
| **3** | **Localization and Mapping in mobile robotics**:<br>Motion Control of Mobile Robots (Model and Motion based Controllers): Lyapunov-based Motion Control Designs and Case Studies. Understand the current application and limitations of Mobile Robots. Introduction to Mobile Manipulators and Cooperative Mobile Robots. Odometry, Dead reckoning method, Map based localisation, Kalman filtering | 7 Hrs |
| **4** | **Micro robotics**: Introduction, Task specific definition of micro-robots - Size and Fabrication Technology based definition of microrobots - Mobility and Functional-based definition of micro- robots - Applications for MEMS based micro-robots. | 7 Hrs |
| **5** | **Micro-robotic actuators**.- Design of locomotive micro-robot devices based on arrayed actuators .Micro-robotic devices: Micro grippers and other micro tools, micro-conveyers- Walking MEMS microrobots- Multi robot system: Micro-robot powering , microrobot communication. | 6 Hrs |
| **6** | **Implementation of Microrobots:** Arrayed actuator principles for micro-robotic applications. Micro fabrication and micro assembly: micro fabrication principles, design selection criteria for micromachining , Packaging and integration aspects, Micro-assembly platforms and manipulators. | 4 Hrs |

**Suggested learning resources:**

**Reference Books:**


1. Atnaik, Srikanta, "Robot Cognition and Navigation: An Experiment with Mobile Robots", Springer-Verlag Berlin and Heidelberg, 2007.
2. Howie Choset, Kevin LynchSeth Hutchinson, George Kantor, Wolfram Burgard, Lydia Kavraki, and Sebastian Thrun, ―Principles of Robot Motion-Theory, Algorithms, and Implementation, MIT Press, Cambridge, 2005.
3. Margaret E. Jefferies and Wai-Kiang Yeap, "Robotics and Cognitive Approaches to Spatial Mapping", Springer-Verlag Berlin Heidelberg 2008.

## Course: Autonomous Robotics and Telecherics (PEC-II)

| Course Code | MRAIPEC506-R | Scheme of Evaluation | MSE TA& ESE |
|---|---|---|---|
| **Teaching Plan** | **3-0-0-0** | **Mid Semester Exam** | 30 |
| **Credits** | 3 | **Teachers' Assessment** | 20 |
| | | **End Sem Exam** | 50 |

**Course Outcomes:**

Students who successfully complete this course will have an ability to:

1. Learn principles of working of autonomous robots.
2. Demonstrate the sensing, perception, and cognition of autonomous robots.
3. understand anatomy of autonomous robots.

**Syllabus:**

| Unit | Contents | Lecture |
|---|---|---|
| **1** | **Introduction to Mobile Robotics Fundamentals:**<br>Overview of mobile robotics principles and locomotion basics.<br>Introduction to kinematics and mobility concepts.<br>Classification of mobile robots and their applications. | 6 Hrs |
| **2** | **AI Techniques for Robot Navigation:**<br>Introduction to AI techniques for robot navigation. Overview of modern mobile robots: Swarm robots, cooperative robots, mobile manipulators.<br>Discussion on current challenges in mobile robotics. | 6 Hrs |
| **3** | **Autonomous Mobile Robots:**<br>Understanding the need and applications of autonomous mobile robots.<br>Sensing technologies for perception in autonomous systems. Localization techniques for self-awareness and position determination. | 6 Hrs |
| **4** | **Mapping and Navigation:**<br>Mapping methods for environment representation and exploration.<br>Navigation principles and control strategies for autonomous motion. Basics of autonomy: Motion control, vision systems, and PID controllers. | 6 Hrs |
| **5** | **Telecheric Robots and Humanoid Robots:**<br>Introduction to telecheric robots and teleoperation concepts. Exploring the need and applications of telecheric robots. Overview of humanoid robots and their functionalities. | 6 Hrs |
| **6** | **Swarm Robotics and Robot Applications:**<br>Understanding swarm robotics principles and collective behaviors. Ethical considerations in robot applications: Privacy, safety, and social impact.<br>Discussion on various robot applications in diverse fields. | 6 Hrs |

**Suggested learning resources:**

**Reference Books:**

1. John M Holland, “Designing Autonomous Mobile Robots”,Elsevier,2004
2. Morgan Quigley, Brian Gerkey Quigley et al, “Programming Robots with ROS” ,O’ Rielly Publishers,Murphy 2000.

3. huzi Sam Ge, Frank L Lewis, “Autonomous Mobile Robots” ,Edited by S,Tylor and Francis, 2006.
4. Roland Siegwart, Illah Reza Nourbakhsh, Davide Sacramuzza, “Introduction to Autonomous Mobile Robots”, MIT press,2nd edition, 2011.
5. Peter Corke, “Robotics Vision and Control”, Springer 2011.

## Course: Data Analytics (PEC-I)

| **Course Code** | MRAIPEC505-A | **Scheme of Evaluation** | MSE TA& ESE |
|---|---|---|---|
| **Teaching Plan** | **3-0-0-0** | **Mid Semester Exam** | 30 |
| **Credits** | 3 | **Teachers' Assessment** | 20 |
| | | **End Sem Exam** | 50 |

**Course Outcomes:**
At the end of the course students will be able to:
1. Examine and compare various datasets and features.
2. Analyze the business issues that analytics can address and resolve.
3. Apply the basic concepts and algorithms of data analytics.
4. Interpret, implement, analyze and validate data using popular data analytics tools.

**Syllabus:**

| Unit | Contents | Lecture |
|---|---|---|
| **1** | **Fundamentals of Data Analytics**<br>Descriptive, Predictive, and Prescriptive Analytics, Data Types, Analytics Types, Data Analytics Steps: Data Pre-Processing, Data Cleaning, Data Transformation, and Data Visualization. | 6 Hrs |
| **2** | **Data Analytics Tools**<br>Data Analytics using Python, Statistical Procedures, NumPy, Pandas, SciPy, Matplotlib | 6 Hrs |
| **3** | **Data Pre-Processing**<br>Understanding the Data, Dealing with Missing Values, Data Formatting, Data Normalization, Data Binning, Importing and Exporting Data in Python, Turning categorical variables into quantitative variables in Python, Accessing Databases with Python. | 6 Hrs |
| **4** | **Data Visualization**<br>Graphic representation of data, Characteristics and charts for effective graphical displays, Chart types- Single var: Dot plot, Jitter plot, Error bar plot , Box-and whisker plot, Histogram, Two variable: Bar chart, Scatter plot, Line plot, Log-log plot, More than two variables: Stacked plots, Parallel coordinate plot. | 6 Hrs |
| **5** | **Descriptive and Inferential Statistics**<br>Probability distributions, Hypothesis testing, ANOVA, Regression | 6 Hrs |
| **6** | **Machine Learning Concepts**<br>Classification and Clustering, Bayes‟ classifier, Decision Tree, Apriori algorithm, K-Means Algorithm, Logistics regression, Support Vector Machines, Introduction to recommendation system. | 6 Hrs |

**Suggested learning resources:**

**Textbooks:**

1. Anil Maheshwari, “Data Analytics made accessible,” Amazon Digital Publication, 2014.
2. James R. Evans, “Business Analytics: Methods, Models, and Decisions”, Pearson 2012
3. Song, Peter X. K, “Correlated Data Analysis: Modeling, Analytics, and Applications”, Springer-Verlag New York 2007.

**Reference Books:**

1. Glenn J. Myatt, Wayne P. Johnson, “Making Sense of Data I: A Practical Guide to Exploratory Data Analysis and Data Mining”, Wiley 2009.
2. Thomas H. Davenport, Jeanne G. Harris and Robert Morison, “Analytics at Work: Smarter Decisions, Better Results”, Harvard Business Press, 2010
3. Rachel Schutt, Cathy O‟Neil, “Doing Data Science”, O‟REILLY, 2006. Shamanth Kumar Fred Morstatter Huan Liu “Twitter Data Analytics”, Springer-Verlag, 2014.

## Course: Deep Learning (PEC-II)

| **Course Code** | MRAIPEC506-A | **Scheme of Evaluation** | MSE TA& ESE |
|---|---|---|---|
| **Teaching Plan** | **3-0-0-0** | **Mid Semester Exam** | 30 |
| **Credits** | 3 | **Teachers’ Assessment** | 20 |
| | | **End Sem Exam** | 50 |

**Course Outcomes:**

Students who successfully complete this course will have an ability to:

1. Understand the fundamentals of neural networks.
2. Design feed forward networks with backpropagation.
3. Analyze neural networks for performance.
4. Apply attention mechanism to the neural network

**Syllabus:**

| **Unit** | **Contents** | **Lecture** |
|---|---|---|
| **1** | **Introduction**<br>Biological Neuron, Idea of computational units, McCulloch–Pitts unit and Thresholding logic, Linear Perceptron, Perceptron Learning Algorithm, Linear separability. Convergence theorem for Perceptron Learning Algorithm. | 6 Hrs |
| **2** | **Neural Network**<br>Introduction to neural network and multilayer perceptrons (MLPs) , representation power of MLPs, sigmoid neurons, gradient descent, feedforward neural networks representation, Backpropagation. | 6 Hrs |
| **3** | **Gradient Descent**<br>Gradient Descent, Batch Optimization, Momentum Based GD, Nesterov Accelerated GD, Stochastic GD, AdaGrad, RMSProp, Adam, Saddle point problem in neural networks, Regularization methods (dropout, drop connect, batch normalization). | 6 Hrs |

| | | |
|---|---|---|
| **4** | **Convolutional Neural Network**<br>Introduction to CNN, Building blocks of C9NN, Transfer Learning, LeNet, AlexNet, ZF-Net, VGGNet, GoogLeNet, ResNet, Visualizing CNNs, Guided Backpropagation, Fooling Convolutional Neural Network | 6 Hrs |
| **5** | **Autoencoders**<br>Autoencoders, Regularization in autoencoders, Denoising autoencoders, Sparse autoencoders, Contractive autoencoders, Regularization: Bias Variance Tradeoff, L2 regularization, Early stopping, Dataset augmentation, Parameter sharing and tying, Injecting noise at input, Ensemble methods, Dropout, Greedy Layerwise Pre-training, Better activation functions, Better weight initialization methods, Batch Normalization. | 6 Hrs |
| **6** | **Recurrent Neural Network**<br>Introduction to RCNN, Backpropagation through time (BPTT), Vanishing and Exploding Gradients, Truncated BPTT, Long ShortTerm Memory, Gated Recurrent Units, Bidirectional LSTMs, Bidirectional RNNs, Encoder Decoder Models, Attention Mechanism. | 6 Hrs |

**Suggested learning resources:**

**Textbooks:**

1. Deep Learning- Ian Goodfelllow, Yoshua Benjio, Aaron Courville, The MIT Press, 2016

**Reference Books:**

1. Neural Networks: A Systematic Introduction, Raúl Rojas, 1996
2. Pattern Recognition and Machine Learning, Christopher Bishop, 2007

## Course: Intelligent Manufacturing (PEC-I)

| **Course Code** | MRAIPEC505-M | **Scheme of Evaluation** | MSE TA& ESE |
|---|---|---|---|
| **Teaching Plan** | **3-0-0-0** | **Mid Semester Exam** | 30 |
| **Credits** | 3 | **Teachers' Assessment** | 20 |
| | | **End Sem Exam** | 50 |

**Course Outcomes:**

Students who successfully complete this course will have an ability to:

1. Summarize the concepts of computer integrated manufacturing systems and manufacturing communication systems
2. Demonstrate the concepts of artificial intelligence and automated process planning
3. Select the manufacturing equipment using knowledge-based system for equipment selection
4. Apply various methods to solve group technology problems and demonstrate the
5. structure for knowledge-based system for group technology

**Syllabus:**

| **Unit** | **Contents** | **Lecture** |
|---|---|---|
| **1** | **Computer Integrated Manufacturing Systems** | 6 Hrs |

| | | |
|---|---|---|
| | Structure and functional areas of CIM system, - CAD, CAPP, CAM, CAQC, ASRS. Advantages of CIM. | |
| **2** | **Manufacturing Communication Systems**<br>MAP/TOP, OSI Model, Data Redundancy, Top- down and Bottom-up Approach, Volume of Information. Intelligent Manufacturing System Components, System Architecture and Data Flow, System Operation. | 6 Hrs |
| **3** | **Basic Components of Knowledge Based Systems**<br>Knowledge Representation, Comparison of Knowledge Representation Schemes, Interference Engine, Knowledge Acquisition. Automated Process Planning - Variant Approach, Generative Approach, Expert Systems for Process Planning, Feature Recognition, Phases of Process planning. | 6 Hrs |
| **4** | **Knowledge Based System for Equipment Selection (KBSES)**<br>Manufacturing system design. Equipment Selection Problem, Modeling the Manufacturing Equipment Selection Problem, Problem Solving approach in KBSES, Structure of the KRSES. | 6 Hrs |
| **5** | **Group Technology**<br>Models and Algorithms Visual Method, Coding Method, Cluster Analysis Method, Matrix Formation - Similarity Coefficient Method, Sorting-based Algorithms, Bond Energy Algorithm, Cost Based method, Cluster Identification Method, Extended CI Method. | 6 Hrs |
| **6** | **Knowledge Based Group Technology**<br>Group Technology in Automated Manufacturing System. Structure of Knowledge based system for group technology (KBSC IT) — Data Base, Knowledge Base, Clustering Algorithm. | 6 Hrs |

**Suggested learning resources:**

**Reference Books:**

Andrew Kusiak, “Intelligent Manufacturing Systems”, 1990

Mohammad Jamshidi, “Design and Implementation of Intelligent Manufacturing Systems:From Expert Systems, Neural Networks to Fuzzy Logic”, 1st Edition,1995

Pat Langley, “Computational Intelligence and Intelligent Systems”, 2006

## Course: Mechatronics System Design (PEC-II)

| **Course Code** | MRAIPEC506-M | **Scheme of Evaluation** | MSE TA& ESE |
|---|---|---|---|
| **Teaching Plan** | **3-0-0-0** | **Mid Semester Exam** | 30 |
| **Credits** | 3 | **Teachers’ Assessment** | 20 |
| | | **End Sem Exam** | 50 |

**Course Outcomes:**

Students who successfully complete this course will have an ability to:

1. Demonstrate how mechatronics integrates knowledge from different disciplines to realize engineering and consumer products that are useful in everyday life.
2. Apply theoretical knowledge: understanding selection of suitable sensors and actuators; designing electro-mechanical systems.
3. Work with mechanical systems that include digital and analogue electronics as a data acquisition model.

**Syllabus:**

| Unit | Contents | Lecture |
|---|---|---|
| **1** | **Mechanical Systems and Design**<br>Mechatronics approach - Control program control, adaptive control and distributed systems - Design process - Types of Design - Integrated product design - Mechanisms, load conditions, design and flexibility Structures, load conditions, flexibility and environmental isolation – Man machine interface, industrial design and ergonomics, information transfer from machine from machine to man and man to machine, safety. | 6 Hrs |
| **2** | **Real time interfacing**<br>Introduction Elements of data acquisition and control Overview of I/O Process-Installation of I/O card & software - Installation of application software, Over framing. | 6 Hrs |
| **3** | **Microcontrollers:**<br>Introduction to use of open-source hardware (Arduino & Raspberry Pi); shields/modules for GPS, GPRS/GSM, Bluetooth, RFID, and Xbee, integration with wireless networks, databases and web pages; web and mobile phone apps. | 6 Hrs |
| **4** | **Case studies on Data Acquisition**<br>Transducer calibration system for Automotive applications Strain Gauge weighing system - Solenoid force - Displacement calibration system - Rotary optical encoder - Inverted pendulum control - Controlling temperature of a hot/cold reservoir -Pick and place robot - Carpark barriers. | 6 Hrs |
| **5** | **Case studies on Data Acquisition and Control**<br>Thermal cycle fatigue of a ceramic plate - pH control system - De-Icing Temperature Control System - Skip control of a CD Player - Autofocus Camera, exposure control. | 6 Hrs |
| **6** | **Case studies on design of Mechatronics products**<br>Motion control using D.C. Motor, A.C. Motor & Solenoids - Car engine management - Barcode reader. | 6 Hrs |

**Suggested learning resources:**

**Textbooks:**


1. W. Bolton, Mechatronics - Electronic Control systems in Mechanical and Electrical Engineering-, 2nd Edition, Addison Wesley Longman Ltd., 1999.
2. Devdas Shetty, Richard A. Kolk, Mechatronics System Design, PWS Publishing company, 1997
3. Bradley, D. Dawson, N.C. Burd and A.J. Loader, Mechatronics: Electronics in Products and Processes, Chapman and Hall, London, 1991.
4. Brian Morris, Automated Manufacturing Systems - Actuators, Controls, Sensors and Robotics, Mc Graw Hill International Edition, 1995.
5. Gopal, Sensors- A comprehensive Survey Vol I & Vol VIII, BCH Publisher.


**Course: Dynamic Control Systems (PEC-I)**

| **Course Code** | MRAIPEC505-C | **Scheme of Evaluation** | MSE TA& ESE |
|---|---|---|---|
| **Teaching Plan** | **3-0-0-0** | **Mid Semester Exam** | 30 |
| **Credits** | 3 | **Teachers' Assessment** | 20 |

| | | | |
|---|---|---|---|
| | | **End Sem Exam** | 50 |

**Course Outcomes:**

Students who successfully complete this course will have an ability to:

1. Understand of Control System Principles
2. Do analysis of Dynamic Systems
3. Acquire knowledge and skills to design control systems using various methods
4. Explore real-world applications of control systems in the field of robotics.

**Syllabus:**

| Unit | Contents | Lecture |
|---|---|---|
| **1** | **Introduction to control and Feedback Control:** Basic principles, Elements of the feedback Loop, Block Diagram, Control Performance, Measures for Common Input Changes, Selection of Variables for Control Approach to Process Control. Factors in Controller Tuning, Determining Tuning Constants for Good Control Performance, Correlations for tuning Constants, Fine Tuning of the controller tuning Constants. The performance of feedback Systems, Practical Application of Feedback Control: Equipment Specification, Input Processing, Feedback Control Algorithm. | 6 Hrs |
| **2** | **Introduction to control and Feedback Control**: Cascade control, Feed forward control, feedback- feed forward control, Ratio control, Selective Control, Split range control- Basic principles, Design Criteria, Performance, Controller Algorithm and Tuning, Implementation issues, Examples and any Special features of the individual loop and industrial applications. | 6 Hrs |
| **3** | **Nonlinear Elements in Loop:** Limiters, Dead Zones, Backlash, Dead Band Velocity Limiting, Negative Resistance, Improvement in nonlinear process performance through: Deterministic Control Loop Calculations, Calculations of the measured variable, final control element selection, cascade control design, Real time implementation issues. | 6 Hrs |
| **4** | **Multivariable Control:** Concept of Multivariable Control: Interactions and it’s effects, Modelling and transfer functions, Influence of Interaction o the possibility of feedback control, important effects on Multivariable system behavior Relative Gain Array, effect of Interaction on stability and Multiloop Control system. Multiloop control Performance through: Loop Paring, tuning, Enhancement through Decoupling, Single Loop Enhancements. | 6 Hrs |
| **5** | **Fuzzy logic systems and Fuzzy controllers** Introduction, Basic Concepts of Fuzzy Logic, Fuzzy Sets, Fuzzy Relation, Fuzzy Graphs, and Fuzzy Arithmetic, Fuzzy If-Then Rules, Fuzzy Logic Applications, Neuro-Fuzzy Artificial Neural networks and ANN controller. | 6 Hrs |
| **6** | **Intelligent Controllers:** Step analysis method for finding first, second and multiple time constants and deadtime. Model Based controllers: Internal Model control, Smith predictor, optimal controller, Model Predictive controller, Dynamic matrix controller (DMC). Self-Tunning Controller. | 6 Hrs |

**Suggested learning resources:**

**Textbooks:**

1. Ogata, “Modern control engineering”, Pearson 2002.
2. Nagraath Gopal “Control Systems Engineering -Principles and Design” New Age Publishers

**Reference Books:**

1. Donald Eckman, & quot;Automatic Process Control", Wiley Eastern Limited.
2. Thomas E Marlin & quot;Process Control- Designing processes and Control Systems for Dynamic Performance& quot;, McGraw-Hill International Editions.
3. F.G.Shinskey, "Process control Systems", TMH.
4. Krishna Kant, "Computer Based Industrial Control", PHI.
5. Chi-Tsong Chen, "Linear System Theory and Design", Oxford University Press.
6. B. C. Kuo, “Automatic Control System”, Prentice Hall of India, 7th edition, 20

## Course: Robot Control Systems

| **Course Code** | MRAIPEC506-C | **Scheme of Evaluation** | MSE & ESE |
|---|---|---|---|
| **Teaching Plan** | **3-0-0-0** | **Scheme of Evaluation** | MSE TA& ESE |
| **Credits** | 3 | **Mid Semester Exam** | 30 |
| | | **Teachers’ Assessment** | 20 |

**Course Outcomes:**

Students who successfully complete this course will have an ability to:

1. This subject is useful to understand the aspects of Design, Analysis of Modern control system with the state space tool.
2. Concept of stability can be obtained for the single input, single output with the help of state space analysis.
3. Concept of compensator/controller will help student to implement in real control system.

**Syllabus:**

| **Unit** | **Contents** | **Lecture** |
|---|---|---|
| **1** | **Introduction to control strategies**: Adaptive control, MPC, nonlinear control. Adaptive Control for Robots: Principles of adaptive control and its applications in robotics, Model reference adaptive control (MRAC) and self-tuning regulators (STR). Adaptive control algorithms for robot manipulators and mobile robots. | 6 Hrs |
| **2** | **Model Predictive Control:** | 6 Hrs |

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|---|---|---|
| | Theory and principles of model predictive control and MPC formulations for robot motion planning and control. Implementation of MPC for trajectory tracking and obstacle avoidance in robot systems. Integration of adaptive control and MPC for robust and adaptive robot control. Case studies and applications of adaptive MPC in robotics | |
| **3** | **Nonlinear Control Techniques:**<br>Introduction to nonlinear control theory,<br>Lyapunov stability theory and its application to nonlinear control and Nonlinear control strategies for robot systems: Feedback linearization, sliding mode control | 6 Hrs |
| **4** | **Multivariable Control Systems:**<br>Concept of multivariable control and its importance, Modeling and transfer functions of multivariable systems, Effects of interactions on stability and performance and Multiloop control system performance enhancement techniques: loop pairing, tuning, decoupling, etc. | 6 Hrs |
| **5** | **Discrete Time System**<br>sampler, sampling process, Laplace transform of sampled function, z transform, z transform of some useful function, stability analysis of Sampled data control system | 6 Hrs |
| **6** | **Reinforcement learning based control.**<br>Overview of reinforcement learning and its core concepts (states, actions, rewards, Q-learning). Introduction to control theory fundamentals (feedback systems, stability analysis).Comparison of traditional control methods with RL for dynamical systems. Importance of stability and safety guarantees in RL-based controllers. Techniques for ensuring stability and safety in RL control algorithms. Introduction to popular software tools for implementing and simulating RL control systems (OpenAI Gym, Stable Baselines3).<br>Exploring RL control applications in various engineering domains (robotics, autonomous vehicles, process control). | 6 Hrs |

# Semester -VI

**Course: Kinematics & Dynamics**

| **Course Code** | MRAIPCC601 | **Scheme of Evaluation** | MSE TA& ESE |
|---|---|---|---|
| **Teaching Plan** | **4-0-0-0** | **Mid Semester Exam** | 30 |
| **Credits** | **4** | **Teachers' Assessment** | 20 |
| | | **End Sem Exam** | 50 |

**Course Outcomes:**

Students who successfully complete this course will have demonstrated an ability to:

1. Understand the fundamental concepts and terminologies related to the kinematics and dynamics of robotic systems.

2. Derive and analyze the forward and inverse kinematics equations for robot manipulators.
3. Analyze and calculate the velocity and acceleration of robot manipulators using the Jacobian matrix and related methods.
4. Comprehend the concept of robot dynamics, including the motion equations and the Newton-Euler equations.
5. Understand the concept of robot control and its relationship with kinematics and dynamics.

**Syllabus:**

| Unit | Contents | Lecture |
|---|---|---|
| **1** | **Introduction**<br>Basic concepts of linear algebra and feedback control, Rigid bodies and homogeneous transformations, Robot modelling | 6 Hrs |
| **2** | **Forward Kinematics**<br>Direct kinematics, Dot and cross products, Co-ordinate frames, Rotations, Homogeneous Coordinates, Link coordinates, D- H Representation, Arm equation, Two axis, three axis, four axis, five axis and six axis robots, Forward kinematics problem | 6 Hrs |
| **3** | **Inverse Kinematics**<br>Inverse Kinematic problem, General properties of solutions, Tool configuration, Inverse Kinematics of Two axis Three axis, Four axis and Five axis robots. | 6 Hrs |
| **4** | **Trajectory planning**<br>Trajectory planning, Geometric Jacobian / Analytical Jacobian, Singularities and redundancy, Inverse kinematics algorithms, Statics and manipulable, Kinematic solutions and trajectory planning. | 6 Hrs |
| **5** | **Robot dynamics**<br>Forward Dynamics and Inverse Dynamics – Importance<br>Spatial description and transformations – Different types of dynamic formulation schemes –Lagrangian formulation for equation of motion for robots and manipulators. Properties of the dynamic model, Dynamic model of simple manipulator structures, Dynamic parameters identification, Operational space dynamics model, Differential kinematics. | 6 Hrs |
| **6** | **Dynamic Modeling**<br>Modeling of motion of robots and manipulators using Newton – Euler equations – State space representation of equation of motion and system properties | 6 Hrs |
| **7** | **Simulation**<br>Importance of Simulation and its types – Numeric Integration solvers and their role in numeric simulation - Numeric simulation of robots and manipulators using MATLAB / Simulink module. | 6 Hrs |
| **8** | **Introduction to Robot Control**<br>Introduction – Need and types of control schemes for robots – joint space control schemes with an example – task space control schemes with an example. | 6 Hrs |

**Suggested learning resources:**

**Textbooks:**

1. Dilip Kumar Pratihar, Fundamentals of Robotics, Narosa Publishing House, (2019).
2. S. K. Saha, Introduction to Robotics 2e, TATA McGraw Hills Education (2014).
3. Asitava Ghoshal, Robotics: Fundamental concepts and analysis, Oxford University Press (2006).
4. J. J. Craig, "Introduction to Robotics: Mechanics and Control", 3rd edition, Addison-Wesley (2003)

**Reference Books:**

1. Siciliano, Bruno. Robotics: modelling, planning and control (online). London: Springer, 2009.
2. Corke, Peter I. Robotics, vision and control: fundamental algorithms in Matlab. 1st ed. New York: Springer, 2011. ISBN 978- 3-642-20143-1.
3. Kelly R, Santibanez V and Loria A, ―Control of Robot M inanipulators in Joint Space‖, Springer, 2005.
4. Devendra K Chaturvedi, ―Modeling and Simulation of Systems using MATLAB and Simulink, CRC press, 2010

## Course: Robot Simulation

| **Course Code** | MRAIPCC602 | **Scheme of Evaluation** | MSE TA& ESE |
|---|---|---|---|
| **Teaching Plan** | **1-0-2-2** | **Mid Semester Exam** | CIE : 100 |
| **Credits** | 1 | **Teachers' Assessment** | |
| | | **End Sem Exam** | |

**Course Outcomes:**

Students who successfully complete this course will have an ability to:

1. Employ MATLAB for robot modeling & control (programming basics, Simulink).
2. Simulate robots (mobile/manipulator), design control (path planning, sensors).
3. Analyze robot performance in simulations (motion, interaction, visualization).
4. Implement advanced control methods (multi-robot systems, reinforcement learning).
5. Utilize Gazebo for high-fidelity robot simulation environments.

**Syllabus:**

| Unit | Contents | Lecture |
|---|---|---|
| **1** | **Introduction to MATLAB:**<br>MATLAB programming basics (variables, data structures, control flow)<br>Introduction to Simulink, SimMechanics & Simscape<br>Creating robot models using Simulink blocks<br>Defining robot parameters (link lengths, masses, inertias)<br>Setting up robot joints and actuators<br>Simulink environment for modeling dynamic systems<br>Various options & tools available in MATLAB Robotics System Toolbox. | 6 Hrs |
| **2** | **Robot Simulation and Analysis:**<br>Simulating robot motion in various environments<br>Introducing sensors and sensor simulation (e.g., ultrasonic sensors, cameras)<br>Simulating robot interactions with objects<br>Performance analysis and visualization of simulation results | 6 Hrs |

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|---|---|---|
| | **Advanced Topics:**<br>Multi-robot systems and coordination<br>Learning control for robots (reinforcement learning)<br>Gazebo co-simulation for high-fidelity environments | |

**Suggested learning resources:**

**Textbooks:**

1. Robotics, Modeling, Planning and Control by Bruno Siciliano

**Reference Books:**

1. Robotics and Control: Fundamental Algorithms in MATLAB by Peter Corke
2. Modeling, Simulation and Control of Robotic Systems(2nd Edition, 2023) by Niku Hedayat
3. MATLAB for Engineers and Scientists (9th Edition, 2023) by Adrian Stern

## Course: Robot Simulation Laboratory

| **Course Code** | MRAIPCC602-L | **Scheme of Evaluation** | MSE & ESE |
|---|---|---|---|
| **Teaching Plan** | **1-0-2-2** | **Term Work** | 50 |
| **Credits** | **1** | **Oral Exam** | 50 |

**Course Outcomes:**

Students who successfully complete this course will have an ability to:

1. Students will develop a solid understanding of dynamic modeling principles for simple mechanical systems using MATLAB.
2. Through numerical simulation experiments, students will acquire skills in simulating and analyzing the behavior of simple mechanical systems, enabling them to predict system responses and identify dynamic characteristics.
3. Students will learn how to analyze the stability of simple mechanical systems using linear system theory techniques
4. developing state space models and performing dynamic simulations using Simulink, students will gain familiarity with state space representation and simulation techniques.

**Course Contents: Assignments / Practical based on: Any Six**

| Expt. No. | Contents | Contact Hours |
|---|---|---|
| **1** | Dynamic model development and simulation of simple mechanical systems using Matlab and Mathematical. | 3 Hrs |
| **2** | Numerical simulation of simple mechanical systems. | 3 Hrs |
| **3** | Stability analysis of simple mechanical systems using linear system theory namely root locus and Bode plot. | 3 Hrs |
| **4** | State space model development and dynamic simulation using Simulink. | 3 Hrs |
| **5** | Implement dynamic simulations of robot systems using Simulink, focusing on state space representation and control system design. | 3 Hrs |
| **6** | Explore different robot configurations (e.g., manipulators, mobile robots) and study their motion characteristics under varying conditions. | 3 Hrs |

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|---|---|---|
| **7** | Develop simulations of sensor fusion algorithms for integrating data from multiple sensors (e.g., cameras, LiDAR, IMU) on robots | 3 Hrs |
| **8** | Simulate the execution of the pick-and-place task and analyze the robot's performance in completing the task. | 3 Hrs |

**Suggested learning resources:**

**Textbooks:**

1. Robotics, Modeling, Planning and Control by Bruno Siciliano

**Reference Books:**

1. Robotics and Control: Fundamental Algorithms in MATLAB by Peter Corke
2. Modeling, Simulation and Control of Robotic Systems(2nd Edition, 2023) by Niku Hedayat
3. MATLAB for Engineers and Scientists (9th Edition, 2023) by Adrian Stern

## Course: Microcontrollers & It's Applications

| **Course Code** | MRAIPCC603 | **Scheme of Evaluation** | MSE TA& ESE |
|---|---|---|---|
| **Teaching Plan** | **2-0-2-2** | **Mid Semester Exam** | 30 |
| **Credits** | 2 | **Teachers' Assessment** | 20 |
| | | **End Sem Exam** | 50 |

**Course Outcomes:**

Students who successfully complete this course will have an ability to:

1. Comprehend and analyze architectures of microprocessors, microcontroller and ARM7 processor
2. Comprehend the memory organization of 8051 microcontroller
3. Comprehend and use peripheral serial communication and the concepts of interrupts in 8051 microcontroller
4. Interface 8051 microcontroller with the input and output devices such as LEDs, LCDs, 7-segment display and keypad
5. Design 8051 microcontroller based system with analog-to-digital converters and digital-to- analog converters within realistic constraints like user specification, availability of components etc.

**Syllabus:**

| Unit | Contents | Lecture |
|---|---|---|
| **1** | **Fundamentals of Microprocessors**<br>Fundamentals of Microprocessor architecture, 8-bitMicroprocessor and Microcontroller architecture, comparison of 8-bit microcontrollers, 16-bit and 32-bit microcontrollers, definition of embedded system and its characteristics, role of microcontrollers in embedded Systems, overview of the 8051 family, introduction to ARM7, Intel I (i3, i5, i7) series processors. | 6 Hrs |
| **2** | **The 8051 Architecture**<br>Internal Block Diagram, CPU, ALU, address, data and control bus, Working registers, SFRs, Clock and RESET circuits, Stack and Stack Pointer, Program Counter, I/O ports, RAM- ROM organization, Memory Structures, Data and Program Memory, Timing diagrams and Machine Cycles. | 6 Hrs |

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|---|---|---|
| 3 | **Instruction Set**<br>Addressing modes: Instruction syntax, Data types, Subroutines Immediate addressing, Register addressing, Direct addressing, Indirect addressing, Relative addressing, Indexed addressing, Bit inherent addressing, bit direct addressing, 8051 Instruction set, Instruction timings, Data transfer instructions, Arithmetic instructions, Logical instructions, Branch instructions, Subroutine instructions, Bit manipulation instruction, Interrupts.<br>**Programming**<br>Assembly language programs, C language programs, Assemblers and compilers, Programming and debugging tools. | 6 Hrs |
| 4 | **I/O and External Communication Interface:**<br>Memory and I/O expansion buses, control signals, memory wait states. Interfacing of peripheral devices such as General Purpose I/O, timers, counters, memory devices, Synchronous and Asynchronous Communication, serial communication, RS232, SPI, I2C. Introduction and interfacing to protocols like Blue-tooth and Zig-bee<br>**Applications**<br>LED, LCD and keyboard interfacing, Stepper motor interfacing, DC Motor interfacing, sensor interfacing, Analog-to-Digital Convertors, Digital-to-Analog Convertors, Sensors with Signal conditioning Interface. | 6 Hrs |

**Suggested learning resources:**

**Textbooks:**


1. M. A.Mazidi, J. G. Mazidi and R. D. McKinlay, “The 8051 Microcontroller and Embedded Systems: Using Assembly and C”, Pearson Education, 2007.
2. K. J. Ayala, “ 8051 Microcontroller” , Delmar Cengage Learning, 2004.
3. R. Kamal, “Embedded System”, McGraw Hill Education, 2009.
4. R. S. Gaonkar, “, Microprocessor Architecture: Programming and Applications with the 8085”, Penram International Publishing, 1996
5. D. A. Patterson and J. H. Hennessy, "Computer Organization and Design: The Hardware/Software interface”, Morgan Kaufman Publishers, 2013.
6. D. V. Hall, “ Microprocessors & Interfacing” , McGraw Hill Higher Education, 1991.


**Reference Books:**


1. Kenneth J. Ayala, “The 8051 Microcontroller Architecture, Programming & Applications”, Penram International, 1991
2. Raj Kamal, “Embedded Systems: Architecture, Programming and Design”, Tata McGraw-Hill Education, 2008.


## Course: Microcontrollers & It's Applications Laboratory

| **Course Code** | MRAIPCC603-L | **Scheme of Evaluation** | MSE & ESE |
|---|---|---|---|
| **Teaching Plan** | 2-0-2-0 | **Term Work** | 50 |
| **Credits** | **1** | **Oral Exam** | 50 |

**Course Outcomes:**

Students who successfully complete this course will have an ability to:

1. Understand and apply the fundamentals of assembly level programming of microprocessors and microcontrollers.
2. Work with microcontroller real time interfaces including GPIO, serial ports, digital-to- analog converters and analog-to-digital converters.
3. Analyze problems and apply a combination of hardware and software to address the problem.

**Course Contents: Assignments / Practical based on: Any Six**

| Expt. No. | Contents | Contact Hours |
|---|---|---|
| **1** | Assignment exploiting the various addressing modes for accessing internal as well as external memory and unconditional/conditional branch, loop control instructions. | 3 Hrs |
| **2** | Stack and Stack arithmetic operations, Subroutines and parameter passing via register, stack. | 3 Hrs |
| **3** | Seven-Segment Display:<br>Drive a seven-segment display to show numbers or characters.<br>Design a program to display a running counter, temperature reading (if interfaced with a sensor), or custom message. | 3 Hrs |
| **4** | UART Communication:<br>Set up communication between two microcontrollers using UART (Universal Asynchronous Receiver Transmitter).<br>Write code to transmit and receive simple data (characters, sensor readings) between the microcontrollers. | 3 Hrs |
| **5** | PWM Signal Generation:<br>Implement Pulse Width Modulation (PWM) to control the brightness of an LED or the speed of a DC motor.<br>Program the microcontroller to generate different PWM duty cycles for varied LED brightness or motor speeds. | 3 Hrs |
| **6** | Interfacing – Push buttons LEDs Key Matrix Seven segment display LCD ADC/DAC Stepper motor | 3 Hrs |
| **7** | Line Follower Robot:<br>Build a line follower robot using a microcontroller, sensors (e.g., infrared sensors), and motors.<br>Program the robot to follow a black line on a white surface using sensor feedback and motor control. | 3 Hrs |
| **8** | Data Logging System:<br>Interface a microcontroller with an SD card or external memory to log sensor data (temperature, humidity) at regular intervals.<br>Program the system to collect and store sensor readings for later analysis on a computer. | 3 Hrs |

## Course: Robot Safety & Maintenance

| **Course Code** | MRAIPCC604 | **Scheme of Evaluation** | MSE TA& ESE |
|---|---|---|---|
| **Teaching Plan** | **2-0-0-1** | **Mid Semester Exam** | 30 |
| **Credits** | **2** | **Teachers' Assessment** | 10 |

| | | **End Sem Exam** | 60 |
|---|---|---|---|

**Course Outcomes:**

Students who successfully complete this course will have an ability to:

1. Understand the safety factors of robots.
2. Know the safety standards in case of Robots.
3. Understand the concept of how to do maintenance.
4. Analyze and rectify the Human errors causing accidents.

**Syllabus:**

| Unit | Contents | Lecture |
|---|---|---|
| **1** | **Introduction to Robot Safety**<br>Introduction, Safety-Related Terms and Definitions, Organizations Concerned with Safety,Introduction, Robotic Safety Problems and Hazards, Use of Robots to Promote Safety ,Weak Points in Planning and Design, \Operations Causing Safety Problems, The Manufacturer's and User's Role in Robot Safety , Safety Considerations in Robot Design, Installation, Programming, and Operation and Maintenance ,Robot Safeguard Methods.<br>**Robot Accidents**<br>Introduction. Real-Life Examples of Robot Accidents Robot Accidents in Japan, Western Europe, and the United States Causes and Characteristics of Robot Accidents Effects of Robot Accidents and Periods Off Work Due to Robot Accidents Robot Accidents at Manufacturer and User Sites Robot Accident Analysis and Prevention | 6 Hrs |
| **2** | **Robot Safety and Safety devices**<br>Introduction, Robot Safety Education, Safety Considerations in Robot Testing and Start-Up, Commissioning, and Acceptance, Safety Considerations in Robot Welding Operations, Robot Safety in the Automobile Industry, Stopping Grippers of Industrial Robots Not Dropping Throwing Work Items When Experiencing Energy Loss or Not Gripping on the Return of Energy , Robot Standardization and Safety Standards, , Safety Devices, STOP type of a Robot, Emergency Stop, Mode select switch, Deadman switch, Safeguards, Operation inside of the safety fence, Safety Procedures for entering the safety fence<br>**Robot Maintenance**<br>Introduction, General Maintenance Functions and Types of Maintenance, Robot Maintenance Needs and Types, Robot Parts and Special Tools for Maintenance and Repair, Robot Warranty Coverage and Preventive Maintenance Kits, Robot Inspection , Some Guidelines for Safeguarding Robot Maintenance Personnel, Some Models Useful in Performing Robot Maintenance. | 6 Hrs |
| **3** | **Human Factors in Robotics**<br>Introduction, Robots Versus Humans , Human Factors' Issues During the Factory Integration of Robotic Systems, Built-In Human Biases and Some Design Improvement Guidelines for Improving Robot Operator Comfort and Productivity, Benefits and Drawbacks of Robotization from the Standpoint of Human Factors and Rules of Robotics with Respect to Humans, Humans at Risk from Robots and Guidelines for Safeguarding the Operator and the Teacher, Human Factors' Considerations to Robotic Safety, Training for | 6 Hrs |

| | | |
|---|---|---|
| | Reducing Human Error in Robotics and Human Error Data in Robotics, Reliability Analysis of a Robot System with Human Error | |
| 4 | **Safety Standards for Robotic Technology**<br>BIS and ISO safety standards for Robots, Safety management system, Hazard identification, Risk analysis and Evaluation, Audit Programme, Preventive Maintenance of Robots,Accident Prevention Techniques, Ergonomics of robots handling, Safety management and management principles, Major accident control, Safety Training, Robotics Safety Requirements. | 6 Hrs |

**Suggested learning resources:**

**Reference Books:**

1. Robot Reliability and Safety, by B.S.Dhillon, 2015
2. Industrial Robotics -Technology ,Programming and Applications, by Nicholas Odrey, 2017
3. Industrial Robotics, Mikell Groover, 2008

## Course: Data Science

| **Course Code** | MRAIPCC605 | **Scheme of Evaluation** | MSE TA& ESE |
|---|---|---|---|
| **Teaching Plan** | **3-0-0-2** | **Mid Semester Exam** | 30 |
| **Credits** | **3** | **Teachers' Assessment** | 20 |
| | | **End Sem Exam** | 50 |

**Course Outcomes:**

Students who successfully complete this course will have an ability to:

1. Work with a data science platform and its analysis techniques.
2. Design efficient algorithms for mining the data from large volumes.
3. Model a framework for Human Activity Recognition.
4. Development with cloud databases.

**Syllabus:**

| Unit | Contents | Lecture |
|---|---|---|
| 1 | **Introduction to Data Science**<br>Introduction to Data Science – Applications - Data Science Process – Exploratory Data analysis – Collection of data, Graphical presentation of data – Classification of data – Storage and retrieval of data – Big data – Challenges of Conventional Systems - Web Data – Evolution Of Analytic Scalability - Analytic Processes and Tools - Analysis vs Reporting - Modern Data Analytic Tools - Statistical Concepts: Sampling Distributions - Re-Sampling - Statistical Inference - Prediction Error. | 6 Hrs |
| 2 | **Predictive Modeling and Machine Learning**<br>Linear Regression – Polynomial Regression, Multivariate Regression, Multilevel Models – Data Warehousing Overview, Bias/Variance Trade Off , K Fold Cross Validation – Data Cleaning and Normalization ,Cleaning Web | 6 Hrs |

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|---|---|---|
| | Log Data – Normalizing Numerical Data , Detecting Outliers ,Introduction to Supervised And Unsupervised Learning, Reinforcement Learning, Dealing with Real World Data – Machine Learning Algorithms , Clustering , Python Based Application. | |
| **3** | **Data Mining Techniques**<br>Rule Induction - Neural Networks: Learning and Generalization - Competitive Learning - Principal Component Analysis and Neural Networks - Fuzzy Logic: Extracting Fuzzy Models from Data - Fuzzy Decision Trees - Stochastic Search Methods- Neuro-Fuzzy Modeling – Association rule mining – Clustering – Outlier Analysis – Sequential Pattern Mining – Temporal mining – Spatial mining – Web min | 6 Hrs |
| **4** | **Frameworks And Visualization**<br>Map Reduce – Hadoop, Hive, MapR – Sharding – NoSQL Databases – Cloud databases - S3 - Hadoop Distributed File Systems – Visualizations - Visual Data Analysis Techniques - Interaction Techniques – Social Network Analysis – Collective Inferencing – Egonets - Systems and Applications. | 6 Hrs |
| **5** | **Data Science Using Python**<br>Introduction to Essential Data Science Packages: NumPy, SciPy, Jupyter, Stats models and Pandas Package – Data Munging: Introduction to Data Munging, Data Pipeline and Machine Learning in Python – Data Visualization Using Matplotlib – Interactive Visualization with Advanced Data Learning Representation in Python. | 6 Hrs |
| **6** | **Natural Language Processing**<br>Introduction to Human language models, ambiguity, processing paradigms; Phases in natural language processing, applications. Text representation in computers, encoding schemes. Ambiguity in Natural Language: Types of ambiguity: lexical, syntactic, semantic. Processing Paradigms in NLP: Rule-based systems. Applications of NLP: Sentiment analysis, Text classification and clustering, Named Entity Recognition (NER), Machine Translation | 6 Hrs |

**Suggested learning resources:**

**Textbooks:**


1. Michael Berthold, David J. Hand, “Intelligent Data Analysis”, Springer, 2007.
2. Anand Rajaraman and Jeffrey David Ullman, “Mining of Massive Datasets”, Cambridge University Press, 2012.
3. Bill Franks, “Taming the Big Data Tidal Wave: Finding Opportunities in Huge Data Streams with Advanced Analytics”, John Wiley & sons, 2012.
4. Jiawei Han, Micheline Kamber “Data Mining Concepts and Techniques”, Second Edition, Elsevier, Reprinted 2008.
5. Rachel Schutt, Cathy O'Neil, “Doing Data Science”, O'Reilly Publishers, 2013.
6. Foster Provost, Tom Fawcet, “Data Science for Business”, O'Reilly Publishers, 2013.
7. Bart Baesens, “Analytics in a Big Data World: The Essential Guide to Data Science and its Applications“, Wiley Publishers, 2014.
8. S. N. Sivanandam, S. N Deepa, “Introduction to Neural Networks Using Matlab 6.0”, Tata McGraw- Hill E ducation, 2006.
9. Frank Pane, “Hands On Data Science and Python Machine Learning”, Packt Publishers, 2017.
10. Seema Acharya, Subhashini Chellapan, “Big Data and Analytics”, Wiley, 2015.

**Course: Seminar on recent advances in R & AI**

| Course Code | MRAIPCC606 | Scheme of Evaluation | MSE & ESE |
|---|---|---|---|
| **Teaching Plan** | **0-0-2-0** | **Term Work** | 50 |
| **Credits** | **1** | **Oral Exam** | 50 |

**Course Outcomes:**

Students who successfully complete this course will have an ability to:

1. Gain a comprehensive understanding of the latest breakthroughs and research directions in both R (Research) methodologies and AI (Artificial Intelligence) applications.
2. Exposed to diverse areas of R & AI, including new research tools, cutting-edge AI algorithms, and their practical applications in various fields.
3. Foster critical thinking skills by encouraging participants to evaluate the potential impact, ethical considerations, and limitations of recent advancements in R & AI.

**Course Contents: Seminar by every students as per the guideline below**

Seminar Format:

1. Each student will present on a chosen topic related to recent advances in R (Research) and AI.
2. Presentations should be clear, concise, and engaging, targeting a broad audience (may include students from other disciplines).
3. Aim for a presentation length of 20-25 minutes, followed by a 5-10 minute discussion period.

Choosing a Topic:

1. Focus on recent advancements within the last 1-2 years.
2. Consider potential areas of overlap between R and AI, such as:
3. Explainable AI (XAI) and its role in research transparency.
4. Utilizing AI for large-scale data analysis in research projects.
5. Emerging AI applications in specific research fields (e.g., drug discovery, medical imaging analysis).
6. Ethical considerations of using AI in research methodologies.
7. Ensure your chosen topic has sufficient depth for a 20-minute presentation while remaining understandable to a broad audience.

Presentation Content:

1. Provide a brief introduction to the relevant background and existing knowledge in your chosen area.
2. Clearly explain the recent advancements you're focusing on, highlighting key findings, methodologies, or applications.
3. Use visuals (diagrams, graphs, images) to enhance your explanation and audience understanding.
4. Discuss the potential impact of these advancements on research and AI as a whole.
5. Briefly touch on any limitations, challenges, or ethical considerations surrounding the topic.

**Course: Arial Robotics Programming Laboratory**

| Course Code | MRAIVSEC607-L | Scheme of Evaluation | MSE & ESE |
|---|---|---|---|
| **Teaching Plan** | 0-0-2-0 | **Term Work** | 50 |
| **Credits** | 1 | **Oral Exam** | 50 |

**Course Contents: Assignments / Practical based on**

Detailed Content :Any six experiments / assignments from the list below (For Total Min. 24 Hours)

| Expt. No. | Contents | Contact Hours |
|---|---|---|
| **1** | Introduction to Drone Technology Lab<br>Overview of the lab equipment and safety protocols<br>Introduction to basic drone components (frame, motors, flight controller)<br>Familiarization with tools and software used in the lab | 4 Hrs |
| **2** | Drone Assembly and Disassembly<br>Step-by-step assembly of a drone kit<br>Understanding the purpose and function of each component<br>Disassembly of the drone for maintenance and troubleshooting | 4 Hrs |
| **3** | Flight Controller Configuration<br>Introduction to flight controller software (e.g., Betaflight, Ardupilot)<br>Basic configuration and calibration of the flight controller<br>Setting up flight modes and failsafes | 4 Hrs |
| **4** | Basic Flight Maneuvers<br>Practice basic flight maneuvers such as takeoff, landing, and hovering<br>Introduction to different flight modes (e.g., stabilized, acro)<br>Understanding control inputs (pitch, roll, yaw) | 4 Hrs |
| **5** | Autonomous Flight<br>Introduction to autonomous flight modes (e.g., GPS-assisted flight)<br>Planning and executing autonomous missions using mission planning software<br>Understanding geofencing and no-fly zones | 4 Hrs |
| **6** | Payload Integration<br>Introduction to different types of payloads (e.g., cameras, sensors)<br>Mounting and integrating payloads onto the drone<br>Testing payload functionality in flight | 4 Hrs |
| **7** | Advanced Flight Maneuvers<br>Practice advanced flight maneuvers such as banked turns, figure-eight patterns<br>Introduction to acrobatic maneuvers (flips, rolls)<br>Flight proficiency assessment | 4 Hrs |
| **8** | Drone Maintenance and Repair<br>Routine maintenance tasks (cleaning, propeller replacement, battery care)<br>Diagnosing and troubleshooting common issues (motor failure, GPS signal loss)<br>Repairing and replacing damaged components | 4 Hrs |
| **9** | Data Collection and Analysis<br>Introduction to data collection techniques (e.g., aerial photography, mapping)<br>Processing and analyzing data collected by drones<br>Applications of drone-collected data in various industries | 4 Hrs |

**Reference Books:**

1. Build Your Own Drone Manual: The practical guide to safely building, operating and maintaining an Unmanned Aerial Vehicle (UAV), by Alex Eliott, 2016, Publisher: Haynes Publishing
2. Introduction to UAV Systems, by Paul Fahlstrom and Thomas Gleason, 2012, CreateSpace Independent Publishing Platform
3. Quadcopter and Drone Photography: How to Bring Your Photography or Videography to the Next Level, by Eric Cheng, 2014, Peachpit Press
4. DIY Drones for the Evil Genius: Design, Build, and Customize Your Own Drones, by Ian Cinnamon and Romi Kadri, 2016, McGraw-Hill Education TAB
5. Drone Technology and Applications, edited by Changdon Kee and Hesham ElSayed, 2019, Wiley-IEEE Press
6. Small Unmanned Aircraft: Theory and Practice, by Randal W. Beard and Timothy W. McLain, 2012, Princeton University Press
7. Drones: Mastering Flight Techniques, by Brian Halliday, 2016, Wiley
8. Aerial Photography and Videography Using Drones, by Eric Cheng, 2015, Peachpit Press
9. Drone Technology: Types, Operations, and Applications, by Kevin Downing, 2020, Nova Science Publishers
10. Drone Operator's Handbook, by Kevin Jenkins, 2017, Independently published.

## Course: Robot Operating System Laboratory

| **Course Code** | MRAIVSEC6E1-L | **Scheme of Evaluation** | MSE & ESE |
|---|---|---|---|
| **Teaching Plan** | **0-0-4-0** | **Term Work** | 50 |
| **Credits** | **2** | **Oral Exam** | 50 |

**Course Outcomes:**

Students who successfully complete this course will have an ability to:

1. Learn fundamentals, including key ROS concepts, tools, and patterns
2. Program robots that perform an increasingly complex set of behaviors, using the powerful packages in ROS
3. See how to easily add perception and navigation abilities to your robots
4. Integrate your own sensors, actuators, software libraries, and even a whole robot into the ROS ecosystem
5. Learn tips and tricks for using ROS tools and community resources, debugging robot behavior using C++ in ROS

**Course Contents: Assignments / Practical based on: Any Eight**

| **Expt. No.** | **Contents** | **Contact Hours** |
|---|---|---|
| **1** | Set up ROS workspaces and package management. | 4 Hrs |
| **2** | ROS Publisher Subscriber architecture application | 4 Hrs |
| **3** | Trajectory optimization | 6 Hrs |
| **4** | Robot motion planning and perception | 6 Hrs |
| **5** | Robot, localization, and simultaneous localization and mapping (SLAM) | 6 Hrs |

| | | |
|---|---|---|
| **6** | Robot Operating System (ROS) for demonstrations and hands-on activities | 6 Hrs |
| **7** | Simulation with ROS- GAZEBO | 6 Hrs |
| **8** | Endowing mobile autonomous robots with planning, perception, and decision- making capabilities | 4 Hrs |
| **9** | Integrate perception modules into ROS-based robot systems | 6 Hrs |
| **10** | Develop custom ROS packages for specific robotic applications | 6 Hrs |

**Suggested learning resources:**

**Textbooks:**

1. Programming Robots with ROS: A Practical Introduction to the Robot Operating System - Morgan Quigley, Brian Gerkey, William D. Smart

**Reference Books:**

1. ROS Robotics Projects: Build and control robots powered by the Robot Operating System, machine learning, and virtual reality - Lentin Joseph

### Course: Autonomous Navigation using SLAM Laboratory

| | | | |
|---|---|---|---|
| **Course Code** | MRAIVSEC6E2-L | **Scheme of Evaluation** | MSE & ESE |
| **Teaching Plan** | **0-0-4-0** | **Term Work** | 50 |
| **Credits** | **2** | **Oral Exam** | 50 |

**Course Outcomes:**

Students who successfully complete this course will have an ability to:

1. Develop ROS environment: Install ROS, set up workspace, and write basic talker-listener nodes in Python.
2. Model robots: Create URDF descriptions for mobile bases and 3-DOF robot arms.
3. Simulate robots in Gazebo: Simulate mobile robots and integrate robot arms for complete systems.
4. Build industrial simulation environments: Design realistic Gazebo environments for industrial robot applications.
5. Implement ROS functionalities: Utilize ROS packages for SLAM, webcam integration, and computer vision with OpenCV.

**Course Contents: Assignments / Practical based on:**

| Expt. No. | Contents | Contact Hours |
|---|---|---|
| **1** | To install ROS and set-up a ROS workspace on a computer. | 4 Hrs |
| **2** | To write ROS talker-listener code in python. | 4 Hrs |
| **3** | To create a mobile robot base URDF model. | 4 Hrs |
| **4** | To create a 3-DOF robot arm URDF model. | 6 Hrs |
| **5** | To simulate a mobile robot base in Gazebo. | 6 Hrs |
| **6** | To attach the robot arm to base and simulate the complete mobile robot in Gazebo. | 6 Hrs |
| **7** | To create an environment in Gazebo for simulating a mobile robot for an industrial application. | 6 Hrs |
| **8** | To implement SLAM for industrial application using ROS open-source packages. | 6 Hrs |
| **9** | To configure and interface a webcam with ROS. | 6 Hrs |

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|---|---|---|
| **10** | To use OpenCV with ROS for a vision application. | 6 Hrs |

**Suggested learning resources:**

**Textbooks:**

1. Introduction to Autonomous Mobile Robotsby Roland Siegwart, Nour R. Nourbakhsh, and Gordon A. pen_spark
2. **SLAM: From Theory to Applications** by Roland Siegwart and Nour Nourbakhsh
3. **Learning Robotics using Python**by Lentin Joseph

## Course: Robot System Design

| **Course Code** | MRAIVSEC6E3 | **Scheme of Evaluation** | MSE & ESE |
|---|---|---|---|
| **Teaching Plan** | **2-0-0-2** | **Mid Semester Exam** | 40 |
| **Credits** | **2** | **End Sem Exam** | 60 |

**Course Outcomes:**

Students who successfully complete this course will have an ability to:

1. Understand the features and uses of Robotic Operating System (ROS) and allied software tools
2. Generate a robot manipulator and its working environment using simulation tools
3. Implement robot navigation and object manipulation for a given application
4. Incorporate and use robot vision for real-world applications

**Syllabus:**

| **Unit** | **Contents** | **Lecture** |
|---|---|---|
| **1** | **Introduction**<br>Industrial Applications of Robots, Industrial Environments and Constraints, Free Open-Source Software for Robot Simulation, Robotic Operating System (ROS), Gazebo, MoveIt, Ubuntu, Python, Installing and Configuring Simulation Software's | 5 Hrs |
| **2** | **Robotic Operating System**<br>Robotic Operating System (ROS) Fundamentals, Building a ROS Application, ROS Services, ROS Actions, Unified Robot Description Format (URDF) | 5 Hrs |
| **3** | **Robot Navigation Slam:**<br>Simultaneous Localization and Mapping (SLAM) implementation with ROS2 packages and C++. Combining mapping algorithms with the localization concepts, Introduction to the Mapping and SLAM concepts and algorithms. Occupancy Grid Mapping, mapping an environment with the Occupancy Grid Mapping algorithm, Grid-based Fast SLAM:- Simultaneous mapping an environment and localize a robot relative to the map with the Grid-based Fast SLAM algorithm, Self-Localisation, Path Planning and Obstacle Avoidance , Map-Building and Map Interpretation, Simultaneous Localization and Mapping, Navigation using Software Tools | 7 Hrs |
| **4** | **Manipulation**<br>Object Manipulation, Manipulation Planning Algorithms, Prehension, Manipulation using Software Tools | 7 Hrs |

| | | |
|---|---|---|
| | **Robot Vision**<br>Object Detection, Pose Estimation, Logical Camera, ROS Tools for Vision | |

**Suggested learning resources:**

**Reference Books:**

1. ROS Robot Programming; Yoon Seok Pyo I Han Cheol Cho I Yoon Jung I Tae Hoon Lim; https://community.robotsource.org/t/download-the-ros-robot-programming-book-for-free/51
2. Morgan Quigley, Brian Gerkey and William D Smart, "Programming Robots with ROS", O'Reilly Media
3. SLAM for dummies; https://dspace.mit.edu/bitstream/handle/1721.1/119149/16-412j-spring-2005/contents/projects/1aslam_blas_repo.pdf

## Course: Mini Project

| **Course Code** | MRAIVSEC6E4 | **Scheme of Evaluation** | MSE & ESE |
|---|---|---|---|
| **Teaching Plan** | **2-0-0-0** | **Term Work** | 50 |
| **Credits** | 2 | **Oral Exam** | 50 |

**Course Outcomes:**

Students who successfully complete this course will have an ability to:

1. Conceive a problem statement either from rigorous literature survey or from the requirements raised from need analysis.
2. Design, implement and test the prototype/algorithm in order to solve the conceived problem.
3. Write a comprehensive report on mini project work.

**Guidelines:**

1. The mini project is a team activity having 3-4 students in a team. Mini projects should include mainly Mechanical Engineering but can be multi-disciplinary too.
2. The mini project may be a complete hardware or a combination of hardware and software. The software part in the mini project should be less than 50% of the total work.
3. Mini Project should cater to a small system required in laboratory or real life.
4. It should encompass components, devices etc. with which functional familiarity is introduced.
5. After interactions with course coordinator and based on comprehensive literature survey/ need analysis, the student shall identify the title and define the aim and objectives of the mini project.
6. Students are expected to detail out specifications, methodology, resources required, critical issues involved in design and implementation and submit the proposal within the first week of the semester.
7. The student is expected to exert on design, development and testing of the proposed work as per the schedule.
8. Completed mini project and documentation in the form of mini project report is to be submitted at the end of semester.

# Semester -VII

**Course: Advanced Robotics Programming (PEC-III)**

| | | | |
|---|---|---|---|
| **Course Code** | MRAIPEC702-R | **Scheme of Evaluation** | MSE TA& ESE |
| **Teaching Plan** | **3-0-0-0** | **Mid Semester Exam** | 30 |
| **Credits** | 3 | **Teachers' Assessment** | 20 |
| | | **End Sem Exam** | 50 |

**Course Outcomes:**

Students who successfully complete this course will have an ability to:

1. Understand the basic principles of Robotics programming and development.
2. Design real world applications using available software.
3. Understand integration technologies and its applications.
4. Identify problems in integrating the system / simulations / programming.

**Syllabus:**

| Unit | Contents | Lecture |
|---|---|---|
| **1** | **Introduction to ROS**<br>Architectural overview of the Robot Operating System, Framework and setup with ROS environment, ROS workspace structure, essential command line utilities. ROS nodes, topics, services, parameters, actions and launch files. Programming nodes, topics, services, actions with C/C++/Python. Real time programming with ROS. Introduction to ROS2 | 7 Hrs |
| **2** | **Robot Simulation Engines**<br>Physics simulations of Robots with Gazebo, Mujoco and Pybullet C++/Python APIs. Coding the BFS and algorithms in C++. Sample-Based and Probabilistic Path Planning and improvement using the classic approach. Programming in Move it framework. | 7 Hrs |
| **3** | **Path Planning and Navigation**<br>Introduction to Path Planning and Navigation, Classic Path Planning, Number of classic path planning approaches that can be applied to low-dimensional robotic systems. | 5 Hrs |
| **4** | **Motion Planning, Mapping**<br>Use of the EKF ROS package to a robot to estimate its pose. Monte Carlo Localization:- The Monte Carlo Localization algorithm which uses particle filters to estimate a robot's pose. Build MCL in C++: - Coding the Monte Carlo Localization algorithm in C++. | 6 Hrs |
| **5** | **Simultaneous Localization and Mapping (SLAM):**<br>SLAM implementation with ROS2 packages and C++. Combining mapping algorithms with the localization concepts. Introduction to the Mapping and SLAM concepts and algorithms. | 6 Hrs |
| **6** | **Occupancy Grid Mapping:**<br>Mapping an environment with the Occupancy Grid Mapping algorithm. Grid-based Fast SLAM:- Simultaneous mapping an environment and localize a robot relative to the map with the Grid-based Fast SLAM algorithm.<br>Concepts of micros, Client library, features of micros, real time operating systems (RTOS- Free RTOS, Zephyr), implementation of micros on ARM/ESP32 based microcontrollers. | 5 Hrs |

**Suggested learning resources:**

**Reference Books:**


1. Aaron Martinez, Enrique Fernandez, “Learning ROS for Robotic Programming”, PACKT publishing, 2013
2. Morgan Quigley, Brian Gerkey, William D Smart, “Programming Robots with ROS”, SPD Shroff Publishers and distributors Pvt Ltd., 2016

3. Lentin Joseph, “Mastering ROS for Robotics Programming: Design, Build and simulate complex robots using ROS” ,PACKT publishing, 2013

## Course: Advanced Artificial Intelligence (PEC-III)

| **Course Code** | MRAIPEC702-A | **Scheme of Evaluation** | MSE TA& ESE |
|---|---|---|---|
| **Teaching Plan** | **3-0-0-0** | **Mid Semester Exam** | 30 |
| **Credits** | 3 | **Teachers’ Assessment** | 20 |
| | | **End Sem Exam** | 50 |

**Course Outcomes:**

Students who successfully complete this course will have an ability to:

1. Explain in detail how the techniques in the perceive-inference-action loop work
2. Choose, compare, and apply suitable basic learning algorithms to simple applications
3. Explain how deep neural networks are constructed and trained, and apply deep neural networks to work with large scale datasets
4. Understand and develop deep reinforcement learning algorithms for suitable applications.

**Syllabus:**

| **Unit** | **Contents** | **Lecture** |
|---|---|---|
| **1** | **Probability Theory and Exact Inference**<br>Overview of Probability Theory and Bayes Networks.<br>Independence, I-Maps, and Undirected Graphical Models. | 5 Hrs |
| **2** | **Local Models and Template Based Representations**.<br>Exact Inference Techniques: Variable Elimination and Clique Trees.<br>Belief Propagation Tree Construction.<br>Introduction to Bayes Networks and Markov Networks. | 6 Hrs |
| **3** | **Approximate Inference and Optimization**<br>Introduction to Optimization Techniques.<br>Approximate Inference Methods: Sampling and Markov Chains.<br>MAP Inference and Inference in Temporal Models.<br>Learning Graphical Models: Parameter Estimation and Bayesian Networks with Shared Parameters. | 6 Hrs |
| **4** | **Learning and Decision Making**<br>Structure Learning and Structure Search in Graphical Models.<br>Handling Partially Observed Data in Structure Learning.<br>Gradient Descent and Expectation-Maximization (EM) Algorithm.<br>Hidden Variables and Undirected Models.<br>Causality and Utility Functions.<br>Decision Problems and Basics of Utility Theory. | 7 Hrs |
| **5** | **Decision Theory and Sequential Decision Making**<br>Introduction to Decision Theory.<br>Expected Utility and Value of Information. | 6 Hrs |
| **6** | **Decision-Making Basics**:<br>Utility Theory and Sequential Decision Problems.<br>Elementary Game Theory Concepts. | 6 Hrs |

| | | |
|---|---|---|
| | Application of Decision Theory in Sample Problems. | |

**Suggested learning resources:**

**Reference Books:**

1. Daphne Koller and Nir Friedman probabilistic graphical Models, MIT Press, 2009
2. Russell and P. Norvig , Artificial Intelligence
3. Cristopher Bishop: pattern Recognition and machine Learning

## Course: Micro Electro-Mechanical Systems(PEC-III)

| **Course Code** | MRAIPEC702-M | **Scheme of Evaluation** | MSE TA& ESE |
|---|---|---|---|
| **Teaching Plan** | **3-0-0-0** | **Mid Semester Exam** | 30 |
| **Credits** | 3 | **Teachers' Assessment** | 20 |
| | | **End Sem Exam** | 50 |

**Course Outcomes:**

Students who successfully complete this course will have demonstrated an ability to:

1. Explain MEMS technology and challenges in it.
2. Understand and explain micro sensors, micro actuators, their types and applications.
3. Explain about fabrication processes for producing micro sensors and actuators.
4. Do material selection appropriately according to fabrication processes

**Syllabus:**

| Unit | Contents | Lecture |
|---|---|---|
| **1** | **Introduction**<br>Overview of MEMS & Microsystems: Definition and history of MEMS Scaling laws and miniaturization effects, Evolution of microsensors, MEMS & microfabrication typical MEMS and Microsystems and miniaturization – applications of Microsystems. Micromachining of novel materials (e.g., polymers, biocompatible materials) | 6 Hrs |
| **2** | **MEMS materials**<br>Materials demand for Extreme conditions of operation, material property mapping, Processing, strengthening methods, treatment, and properties.<br>Overview of Smart Materials, Structures and Products Technologies Smart Materials (Physical Properties) Piezoelectric Materials, Electro strictive Materials, Magneto strictive Materials, Magneto electric Materials, Magneto rheological Fluids Electro rheological Fluids, Shape Memory Materials, Bio-Materials, metal matrix composites (MMC), their applications in aerospace and automobiles, Superplastic materials | 7 Hrs |
| **3** | **MEMS Design Principles**<br>Mechanical design considerations (stress, strain, beam mechanics)<br>Electrical design considerations (electrostatics, magnetics)<br>Microfluidic design principles, Micro-Nano Fluidics, MEMS reliability and testing | 5 Hrs |
| **4** | **Micro manufacturing/Micro fabrication**<br>Preparation of the substrate, Physical Vapor Deposition, Chemical Vapor Deposition, Ion Implantation, Coatings for high temperature performance, | 6 Hrs |

| | | |
|---|---|---|
| | Electrochemical and spark discharge and Plasma coating methods, electron beam and laser surface processing, Organic and Powder coatings, Thermal barrier coating, LIGA process | |
| **5** | **Micro sensors**<br>Smart Sensor, Actuator and Transducer Technologies, Smart Sensors: Accelerometers; Force Sensors; Load Cells; Torque Sensors; Pressure Sensors; Microphones; Sensor Arrays Micro actuators | 6 Hrs |
| **6** | **Smart Actuators:**<br>Displacement Actuators; Force Actuators; Power Actuators; Vibration Dampers; Shakers; micro–Fluidic Pumps; micro Motors Smart Transducers: Ultrasonic Transducers; Sonic Transducers. | 6 Hrs |

**Suggested learning resources:**

**Reference Books:**


1. Tai Ran Hsu, "MEMS and Microsystems: Design and Manufacture", Tata McGraw Hill, 2002.
2. M.V. Gandhi and B.S. Thompson, "Smart Materials and Structures", Chapman & Hall, London; New York, 1992 .
3. Westbrook J.H & Fleischer R.L., "Micro sensors, MEMS and smart Devices", Julian W. Gardner & Vijay K. Varadan, John Wiley & Sons, 2001.
4. A.V. Srinivasan, "Smart Structures: Analysis and Design", Cambridge University Press, Cambridge; New York, 2001 (ISBN: 0521650267).
5. B. Culshaw, "Smart Structures and Materials", Artech House, Boston, 1996


## Course: Advanced Control System (PEC-III)

| **Course Code** | MRAIPEC702-C | **Scheme of Evaluation** | MSE TA& ESE |
|---|---|---|---|
| **Teaching Plan** | **3-0-0-0** | **Mid Semester Exam** | 30 |
| **Credits** | 3 | **Teachers' Assessment** | 20 |
| | | **End Sem Exam** | 50 |

**Course Outcomes:**

Students who successfully complete this course will have an ability to:

1. Demonstrate non-linear system behaviour by phase plane and describing function methods
2. Perform the stability analysis nonlinear systems by Lyapunov method
3. Develop design skills in optimal control problems
4. Derive discrete-time mathematical models in both time domain (difference equations, state equations) and z domain (transfer function using z-transform).
5. Predict and analyze transient and steady-state responses and stability and sensitivity of both open-loop and closed-loop linear, time-invariant, discrete-time control systems.
6. Acquire knowledge of state space and state feedback in modern control systems, pole placement, design of state observers and output feedback controllers.

**Syllabus:**

| **Unit** | **Contents** | **Lecture** |
|---|---|---|

| | | |
|---|---|---|
| **1** | State space analysis state space representation, solution of state equation, state transition matrix, canonical forms – controllable canonical form, observable canonical form, jordan canonical form. Tests for controllability and observability for continuous time, systems – time varying case, minimum energy control, time invariant case, | 6 Hrs |
| **2** | Principle of duality, controllability and observability form jordan canonical form and other canonical forms. Describing function analysis -introduction to nonlinear systems, types of nonlinearities, describing functions, describing function analysis of nonlinear control systems. Phase-plane analysis introduction to phase-plane analysis, method of isoclines. | 6 Hrs |
| **3** | For constructing trajectories, singular points, phase-plane analysis of nonlinear control systems. Stability analysis stability in the sense of lyapunov., lyapunov's stability and lypanov's instability theorems. Direct method of lyapunov for the linear and nonlinear continuous time autonomous systems. | 6 Hrs |
| **4** | Modal control effect of state feedback on controllability and observability, design of state feedback control through pole placement. Full order observer and reduced order observer. Calculus of variations minimization of functionals of single function, constrained minimization. Minimum principle. Control variable inequality constraints. Control and state variable inequality constraints. | 6 Hrs |
| **5** | Euler Lagrange equation. Optimal control formulation of optimal control problem. Minimum time, minimum energy, minimum fuel problems. | 6 Hrs |
| **6** | State regulator problem. Output regulator problem. Tracking problem, continuous-time linear regulators | 6 Hrs |

**Suggested learning resources:**

**Textbooks:**

1. M. Gopal, Digital Control and State Variable Methods, Tata Mc Graw-Hill Companies, 1997.
2. M. Gopal Modern Control System Theory, New Age International Publishers, 2nd edition, 1996

**Reference Books:**

1. K. Ogata, "Modern Control Engineering", Prentice Hall of India, 3rd edition, 1998
2. I.J. Nagrath and M. Gopal, "Control Systems Engineering", New Age International (P) Ltd, 2017
3. Stainslaw H. Zak, "Systems and Control", Oxford Press, 2003.

## Course: Biomedical Robotics(PEC-IV)

| **Course Code** | MRAIPEC703-R | **Scheme of Evaluation** | MSE TA& ESE |
|---|---|---|---|
| **Teaching Plan** | **3-0-0-0** | **Mid Semester Exam** | 30 |
| **Credits** | 3 | **Teachers' Assessment** | 20 |
| | | **End Sem Exam** | 50 |

**Course Outcomes:**

Students who successfully complete this course will have an ability to:

1. Identify and describe different types of medical robots and their potential applications
2. Know basic concepts in kinematics, dynamics, and control relevant to medical robotics
3. Understanding and analyzing biological signals (motion, muscle and brain activity)
4. Develop the analytical and experimental skills necessary to design and implement robotic assistance for different biomedical applications
5. Be familiar with the state of the art in applied medical robotics and medical robotics research

**Syllabus:**

| Unit | Contents | Lecture |
|---|---|---|
| **1** | **Introduction to Robotics**<br>Definition and history of robots<br>Robot classifications (e.g., industrial, service, mobile)<br>**Biocompatibility and Safety in Robotics**<br>Biomaterials and their interaction with living tissues<br>Sterilization and disinfection techniques for robots<br>Safety considerations for surgical robots and patient well-being<br>Regulatory frameworks for medical devices | 7 Hrs |
| **2** | **Robot Kinematics**<br>Introduction to forward kinematics & inverse kinematics<br>Rigid Motions, Homogeneous transformations Forward/Inverse Kinematics Jacobian, redundant motions and singularities. Forward/Inverse Dynamics Force/Motion Control | 6 Hrs |
| **3** | **Biological Robot Control**<br>Biological movement control Robots for biomedical research teleoperation, cooperative manipulation, robots for endoscopy Physical human-robot interaction .Issues in the Control of Prosthetic Limbs | 6 Hrs |
| **4** | **Surgical Robots Biomimetic systems** :<br>Biomimetic robotics Surgery robotics Neuro-Rehabilitation Robotics Prosthetics Assistive robotics soft robotics for biomedical applications. Telepresence surgery and its benefits, Haptic feedback technologies for realistic manipulation, Computer vision and image guidance in robotic surgery, Future advancements in robot-assisted surgery | 6 Hrs |
| **5** | **Ethics in Biomedical Robotics**<br>Ethical considerations in surgical decision-making with robots, Human-robot interaction and the role of the surgeon, Job displacement in healthcare due to automation, Access to robotic technologies and healthcare disparities | 5 Hrs |
| **6** | **Medical Applications of Robotics:**<br>Minimally Invasive Surgery (MIS): Laparoscopic surgery and robotic-assisted laparoscopic surgery (RALS), Robotic arms and instruments for MIS<br>Rehabilitation Robotics: Exoskeletons for gait training and movement assistance, Robotic therapy for stroke and neurological disorders<br>Assistive Technologies: Robotic prosthetics and orthotics, Surgical robots for joint replacement | 6 Hrs |

**Suggested learning resources:**

**Reference Books:**

1. Siciliano, B., Sciavicco, L. Villani, L . and Oriolo, “Robotics. Modeling, Planning and Control”, Springer. 2009
2. Habib, "Handbook of Research on Biomimetics and Biomedical Robotics Advances in Computational Intelligence and Robotics”(2327-0411), Maki Publishers, 2017

## Course: Augmented Reality and Virtual Reality(PEC-IV)

| **Course Code** | MRAIPEC703-A | **Scheme of Evaluation** | MSE TA& ESE |
|---|---|---|---|
| **Teaching Plan** | **3-0-0-0** | **Mid Semester Exam** | 30 |
| **Credits** | 3 | **Teachers’ Assessment** | 20 |
| | | **End Sem Exam** | 50 |

**Course Outcomes:**

Students who successfully complete this course will have an ability to:

1. Understand and analyze the hardware requirement of AR.
2. Describe AR systems work and list the applications of AR.
3. Understand the design and implementation of the hardware that enables VR systems to be built.
4. Explain the concepts of motion and tracking in VR systems.

**Syllabus:**

| Unit | Contents | Lecture |
|---|---|---|
| **1** | **Introduction to Augmented Reality**<br>Defining augmented reality, history of augmented reality, The Relationship Between Augmented Reality and Other Technologies-Media, Technologies, Other Ideas Related to the Spectrum Between Real and Virtual Worlds, applications of augmented reality, Working, Concepts Related to Augmented Reality, Ingredients of an Augmented Reality Experience. | 6 Hrs |
| **2** | **Augmented Reality Architecture**<br>Audio Displays, Haptic Displays, Visual Displays, Other sensory displays, Visual Perception, Requirements and Characteristics, Spatial Display Model. Processors – Role of Processors, Processor System Architecture, Processor Specifications. Tracking & Sensors - Tracking, Calibration, and Registration, Characteristics of Tracking Technology, Stationary Tracking Systems, Mobile Sensors, Optical Tracking, Sensor Fusion. | 6 Hrs |
| **3** | **AR Techniques**<br>Marker-based approach- Introduction to marker-based tracking, types of markers, marker camera pose and identification, visual tracking, mathematical representation of matrix multiplication Marker types- Template markers, 2D barcode markers, imperceptible markers. Marker-less approach- Localization based augmentation, real world examples Tracking methods- Visual tracking, feature based tracking, hybrid tracking, and initialisation and recovery | 6 Hrs |
| **4** | **Introduction to Virtual Reality** | 6 Hrs |

| | | |
|---|---|---|
| | Defining Virtual Reality, History of VR, Human Physiology and Perception, Key Elements of Virtual Reality Experience, Virtual Reality System, Interface to the Virtual World-Input & output- Visual, Aural & Haptic Displays, Applications of Virtual Reality | |
| **5** | **Virtual World Motion tracking**<br>Representation of the Virtual World, Visual Representation in VR, Aural Representation in VR and Haptic Representation in VR, Motion in Real and Virtual Worlds- Velocities and Accelerations, The Vestibular System, Physics in the Virtual World, Mismatched Motion and Vection Tracking- Tracking 2D & 3D Orientation, Tracking Position and Orientation, Tracking Attached Bodies | 6 Hrs |
| **6** | **Virtual Worlds & Human Vision**<br>Geometric Models, Changing Position and Orientation, Axis-Angle Representations of Rotation, Viewing Transformations, Chaining the Transformations, Human Eye, eye movements & implications for VR. | 6 Hrs |

**Suggested learning resources:**

**Textbooks:**


1. Steven M. LaValle, "Virtual Reality", Cambridge University Press, 2016
2. William R Sherman, Alan B Craig, "Understanding Virtual Reality: Interface, Application and Design",, "The Morgan Kaufmann Series in Computer Graphics", Morgan Kaufmann Publishers, San Francisco, CA, 2002
3. Developing Virtual Reality Applications: Foundations of Effective Design, Alan B Craig, William R Sherman and Jeffrey D Will, Morgan Kaufmann, 2009.


**Reference Books:**


1. Gerard Jounghyun Kim, "Designing Virtual Systems: The Structured Approach", 2005.
2. Doug A Bowman, Ernest Kuijff, Joseph J LaViola, Jr and Ivan Poupyrev, "3D User Interfaces, Theory and Practice", Addison Wesley, USA, 2005.
3. Oliver Bimber and Ramesh Raskar, "Spatial Augmented Reality: Merging Real and Virtual Worlds", 2005.
4. Burdea, Grigore C and Philippe Coiffet, "Virtual Reality Technology", Wiley Interscience, India, 2003.


## Course: Advanced Mechatronics (PEC-IV)

| **Course Code** | MRAIPEC703-M | **Scheme of Evaluation** | MSE TA& ESE |
|---|---|---|---|
| **Teaching Plan** | **3-0-0-0** | **Mid Semester Exam** | 30 |
| **Credits** | 3 | **Teachers' Assessment** | 20 |
| | | **End Sem Exam** | 50 |

**Course Outcomes:**

Students who successfully complete this course will have an ability to:

1. Acquire knowledge of Mechatronic systems and its design
2. Gain Knowledge of Microcontrollers and its operation.
3. Perform experiments on Microcontrollers.

**Syllabus:**

| Unit | Contents | Lecture |
|---|---|---|
| **1** | **Introduction to Advanced Mechatronics:**<br>Review of fundamental mechatronic principles, Introduction to advanced mechatronic systems, Applications of advanced mechatronics Introduction to theoretical and applied mechatronics, design and operation of mechatronics systems; mechanical, electrical, electronic, and opto-electronic components; sensors and actuators including signal conditioning and power electronics | 7 Hrs |
| **2** | **Advanced Control Systems:**<br>Robust control design, Adaptive control, Optimal control Microcontrollers—fundamentals, programming, and interfacing; and feedback control. Includes structured and term projects in the design and development of proto-type integrated mechatronic systems. | 6 Hrs |
| **3** | **Mechatronic System Design**<br>Design methodologies for mechatronic systems, Actuator and sensor selection, System integration and packaging, Mechatronic System Simulation and Design | 6 Hrs |
| **4** | **Advanced Modelling Techniques**<br>Nonlinear system modelling, multi-body system dynamics, Finite element analysis for mechatronics | 5 Hrs |
| **5** | **Microcontroller**<br>Introduction to applications of and hands-on experience with microcontrollers and single-board computers for embedded system applications. Specifically, gain familiarity with the fundamentals, anatomy, functionality, programming, interfacing, and protocols for the Arduino microcontroller, multi-core Propeller microcontroller, and single-board computer Raspberry Pi. | 7 Hrs |
| **6** | **Advanced Mechatronics Applications**<br>Mechatronics in robotics, Smart machines and intelligent systems, Biomechatronic | 5 Hrs |

**Suggested learning resources:**

**Reference Books:**


1. Kenneth J Ayala, "The 8051 Microcontroller Programming and Architecture", 1996.
2. Raj Kamal, "Embedded systems Architecture, Programming and design", Tata McGraw hill Education 2008.


**Course: Robot Dynamics and Control (PEC-IV)**

| Course Code | MRAIPEC703-C | Scheme of Evaluation | MSE TA& ESE |
|---|---|---|---|
| **Teaching Plan** | **3-0-0-0** | **Mid Semester Exam** | 30 |
| **Credits** | 3 | **Teachers' Assessment** | 20 |
| | | **End Sem Exam** | 50 |

**Course Outcomes:**

Students who successfully complete this course will have an ability to:

1. Select, design, analyze, implement, and evaluate effective controllers for a number of different robotics platforms and applications.
2. The dynamics of robot arms, mobile robots and quadrotors
3. Position and force control for robots.
4. How to generate complex trajectories
5. Controller synthesis and stability

**Syllabus:**

| Unit | Contents | Lecture |
|---|---|---|
| **1** | **Introduction :**<br>Degrees of freedom and robot configurations, Robot anatomy: links, joints, and end-effectors, Robot coordinate systems Rigid-body, DoF, Rotation and Forward Kinematics. Inverse Kinematics Workspace, Rigid Body Dynamics. Dynamics of Robot Arms | 7 Hrs |
| **2** | **Robot Kinematics:**<br>Kinematics fundamentals: position, velocity, and acceleration, Forward kinematics: calculating the position of the end-effector based on joint angles, Inverse kinematics: finding the required joint angles to achieve a desired end-effector position, Denavit-Hartenberg (DH) convention and homogeneous transformations | 6 Hrs |
| **3** | **Robot Dynamics:**<br>Introduction to robot dynamics forces, torques, and their effect on motion Lagrangian and Newtonian approaches to deriving robot dynamic equations. Analyzing dynamic properties like inertia and gravity | 5 Hrs |
| **4** | **System Dynamics and Control:**<br>Modelling of electrical, mechanical, and electromechanical systems. Analytic solution of open loop and feedback type systems. Root Locus methods in design of systems and evaluation of system performance. Time and frequency domain | 5 Hrs |
| **5** | **Trajectory Planning and Control :**<br>Motion planning: specifying desired robot paths and tasks, Defining velocity and acceleration profiles for smooth motion, Trajectory generation techniques (e.g., joint interpolation, minimum jerk), Introduction to Linear Control, State Space Modeling and Multivariable Systems, Nonlinear Control, Stability Theory Quadrotor Control Trajectory Generation Planning and Control of a Quadrotor design of control systems. | 6 Hrs |
| **6** | **Workspace Analysis and Manipulability:**<br>Workspace visualization: techniques for understanding the reachable space of a robot, Manipulability measures: dexterity and ease of motion within the workspace.<br>**Dynamics and Control of Wheeled Mobile Robots**<br>Kinematic and dynamic modeling of wheeled robots (differential drive, omni-directional), Trajectory tracking and control for wheeled robots, Obstacle avoidance and path planning algorithms | 7 Hrs |

**Suggested learning resources:**

**Textbooks:**

1. Saeed B. Niku, "Introduction to Robotics – Analysis, Control, Applications", Wiley India Pvt. Ltd., 2010

2. S. K. Saha, “Introduction to Robotics”, McGraw Hill Education (India) Pvt. Ltd.,2014
3. Choset, Lynch, Hutchinson, Kantor, Burgard, Kavraki and Thrun, “Principle of Robot Motion”, PHI Learning Pvt. Ltd., 200

## Course: Robot System Design

| **Course Code** | MRAIVSEC6E3 | **Scheme of Evaluation** | MSE TA& ESE |
|---|---|---|---|
| **Teaching Plan** | **2-0-0-2** | **Mid Semester Exam** | 30 |
| **Credits** | **2** | **Teachers' Assessment** | 20 |
| | | **End Sem Exam** | 50 |

**Course Outcomes:**

Students who successfully complete this course will have an ability to:

1. Understand the features and uses of Robotic Operating System (ROS) and allied software tools
2. Generate a robot manipulator and its working environment using simulation tools
3. Implement robot navigation and object manipulation for a given application
4. Incorporate and use robot vision for real-world applications

**Syllabus:**

| **Unit** | **Contents** | **Lecture** |
|---|---|---|
| **1** | **Introduction**<br>Industrial Applications of Robots, Industrial Environments and Constraints, Free Open-Source Software for Robot Simulation, Robotic Operating System (ROS), Gazebo, Move-it, Ubuntu, Python, Installing and Configuring Simulation Software's | 5 Hrs |
| **2** | **Robotic Operating System**<br>Robotic Operating System (ROS) Fundamentals, Building a ROS Application, ROS Services, ROS Actions, Unified Robot Description Format (URDF) | 5 Hrs |
| **3** | **Robot Navigation Slam:**<br>Simultaneous Localization and Mapping (SLAM) implementation with ROS2 packages and C++. Combining mapping algorithms with the localization concepts, Introduction to the Mapping and SLAM concepts and algorithms. Occupancy Grid Mapping, mapping an environment with the Occupancy Grid Mapping algorithm, Grid-based Fast SLAM:- Simultaneous mapping an environment and localize a robot relative to the map with the Grid-based Fast SLAM algorithm, Self-Localisation, Path Planning and Obstacle Avoidance , Map-Building and Map Interpretation, Simultaneous Localization and Mapping, Navigation using Software Tools | 7 Hrs |
| **4** | **Manipulation**<br>Object Manipulation, Manipulation Planning Algorithms, Prehension, Manipulation using Software Tools<br>**Robot Vision**<br>Object Detection, Pose Estimation, Logical Camera, ROS Tools for Vision | 7 Hrs |

**Suggested learning resources:**

**Reference Books:**


1. ROS Robot Programming; Yoon Seok Pyo I Han Cheol Cho I Yoon Jung I Tae Hoon Lim; https://community.robotsource.org/t/download-the-ros-robot-programming-book-for-free/51
2. Morgan Quigley, Brian Gerkey and William D Smart, “Programming Robots with ROS”, O'Reilly Media
3. SLAM for dummies; https://dspace.mit.edu/bitstream/handle/1721.1/119149/16-412j-spring-2005/contents/projects/1aslam_blas_repo.pdf

**Course: ROS & SLAM Laboratory**

| Course Code | MRAIPCC704 | Scheme of Evaluation | MSE & ESE |
|---|---|---|---|
| **Teaching Plan** | **0-0-4-0** | **Term Work** | 50 |
| **Credits** | **2** | **Oral Exam** | 50 |

**Course Outcomes:**

Students who successfully complete this course will have an ability to:

1. Learn fundamentals, including key ROS concepts, tools, and patterns
2. Model & Simulate robots in Gazebo: Create URDF descriptions for mobile bases and 3-DOF robot arms.
3. Implement ROS functionalities: Utilize ROS packages for SLAM, webcam integration, and computer vision with OpenCV.
4. Program robots that perform an increasingly complex set of behaviors, using the powerful packages in ROS
5. Integrate your own sensors, actuators, software libraries, and even a whole robot into the ROS ecosystem

**Course Contents: Assignments / Practical based on: Any Eight**

| Expt. No. | Contents | Contact Hours |
|---|---|---|
| **1** | To create a Mobile robot base URDF model. | 6 Hrs |
| **2** | To create 3-DOF robot arm URDF model. | 6 Hrs |
| **3** | To attach the robot arm to base and simulate the complete mobile robot in Gazebo. | 6 Hrs |
| **4** | To implement SLAM for industrial application using ROS open-source packages. | 6 Hrs |
| **5** | To configure and interface a webcam with ROS & To use OpenCV with ROS for a vision application. | 6 Hrs |
| **6** | Simulation with ROS- GAZEBO | 6 Hrs |
| **7** | Robot motion planning, perception & trajectory optimization using ROS | 6 Hrs |
| **8** | Robot Operating System (ROS) for demonstrations and hands-on activities | 6 Hrs |
| **9** | Endowing mobile autonomous robots with planning, perception, and decision- making capabilities | 6 Hrs |
| **10** | Integrate perception modules into ROS-based robot systems | 6 Hrs |

**Suggested learning resources:**

**Textbooks:**


1. Introduction to Autonomous Mobile Robots by Roland Siegwart, Nour R. Nourbakhsh, and Gordon A.
2. SLAM: From Theory to Applications by Roland Siegwart and Nour Nourbakhsh
3. Learning Robotics using Python by Lentin Joseph

## Course: Robot operating System

| Course Code | MRAIPCC706 | Scheme of Evaluation | MSE TA& ESE |
|---|---|---|---|
| **Teaching Plan** | **4-0-0-0** | **Mid Semester Exam** | 30 |
| **Credits** | **4** | **Teachers' Assessment** | 20 |
| | | **End Sem Exam** | 50 |

**Course Outcomes:**

Students who successfully complete this course will have an ability to:

1. Understand the core concepts of ROS, including nodes, topics, messages, services, and packages.
2. Install and configure ROS on a development machine.
3. Write basic ROS nodes using a chosen programming language (e.g., Python, C++).
4. Utilize ROS tools for communication, visualization, debugging, and logging.
5. Design and implement robot applications using ROS packages and tools.

**Syllabus:**

| Unit | Contents | Lecture |
|---|---|---|
| **1** | **Introduction to ROS:** Introduction to robotics and robot software development, Overview of ROS and its architecture, Advantages and Applications of ROS, Setting up a ROS development environment. | 6 Hrs |
| **2** | **ROS Fundamentals** Nodes, Topics, Messages, and Services in ROS, ROS Communication: Publishers and Subscribers, Data types and message definition with ROS messages (.msg), Introduction to ROS services (request-reply communication), Introduction to packages and package management | |
| **3** | **Data and Messages in ROS** Data types and message definition with ROS messages (.msg), Introduction to ROS services (request-reply communication), Introduction to packages and package management | |
| **4** | **Programming with ROS**: Introduction to ROS with a chosen programming language (e.g., Python, C++), Creating simple ROS nodes in the chosen language, Publishing and subscribing to topics, Sending, and receiving ROS service requests, Working with ROS libraries and APIs | 6 Hrs |
| **5** | **Robot Navigation with ROS** Explore robot navigation challenges and solutions, Discover popular ROS navigation frameworks (e.g., MoveIt), Learn about path planning, localization, and obstacle avoidance, Understand how ROS enables autonomous robot movement. | |
| **6** | **Robot Perception with ROS** Grasp the importance of robot perception for navigation and interaction, Explore how ROS integrates with sensors like LiDAR and cameras, Understand basic concepts in robot perception (e.g., object detection), Learn how robots "see" and interpret their environment. | |
| **7** | **Advanced ROS Topic**: | 6 Hrs |

| | | |
|---|---|---|
| | Introduction to ROS tools (rviz, rqt, rosbag, etc.) for visualization, debugging, and logging, Working with robot simulations in ROS (e.g., Gazebo), Introduction to robot navigation frameworks (e.g., Moveit) Introduction to robot perception with ROS | |
| **8** | **Interfacing with Sensors and Actuators**: Introduction to robot sensors and actuators, Interfacing sensors and actuators with ROS drivers. Reading sensor data and controlling actuators through ROS nodes | 6 Hrs |

**Suggested learning resources:**

**Textbooks:**

1. Programming Robots with ROS: A Practical Introduction to the Robot Operating System - Morgan Quigley, Brian Gerkey, William D. Smart

**Reference Books:**

1. ROS Robotics Projects: Build and control robots powered by the Robot Operating System, machine learning, and virtual reality - Lentin Joseph

# Semester -VIII

### Course: Agricultural Robotics (PEC-V)

| Course Code | MRAIPEC801-R | Scheme of Evaluation | MSE TA& ESE |
|---|---|---|---|
| Teaching Plan | 3-0-0-0 | Mid Semester Exam | 30 |
| Credits | 3 | Teachers' Assessment | 20 |
| | | End Sem Exam | 50 |

**Course Outcomes:**

Students who successfully complete this course will have an ability to:

1. Gain proficiency in Agricultural Robotics:
2. Get sensing and Perception Expertise:
3. Get navigation and Automation Skills:
4. Obtain data Analysis and Decision-Making Capability

**Syllabus:**

| Unit | Contents | Lecture |
|---|---|---|
| 1 | **Introduction to Agricultural Robotics**<br>Overview of agricultural robotics and its significance in modern agriculture, Evolution and current trends in agricultural robotics, Role of robotics in improving efficiency, productivity, and sustainability in agriculture, Introduction to key components and subsystems of agricultural robots, Ethical, social, and environmental considerations in agricultural robotics | 6 Hrs |
| 2 | **Sensing and Perception in Agricultural Robotics**<br>Fundamentals of sensing technologies used in agricultural robotics, Types of sensors for measuring soil properties, plant health, and environmental parameters, Image processing, and computer vision techniques for crop monitoring and yield estimation, Sensor fusion for multi-modal data integration in agricultural robotics, Challenges, and solutions in robust perception for agricultural robots | 6 Hrs |
| 3 | **Navigation and Localization in Agricultural Environments**<br>Navigation techniques for agricultural robots, including GPS, GNSS, and RTK systems, Localization algorithms for precise positioning in outdoor and indoor agricultural environments, Path planning and obstacle avoidance strategies for safe and efficient robot navigation, Integration of perception and mapping for autonomous navigation, Case studies on real-world navigation challenges in agricultural robotics | 6 Hrs |
| 4 | **Robotic Manipulation and Automation in Agriculture**<br>Robotic arms and grippers for manipulation of agricultural objects, Kinematics and dynamics of robotic manipulators, Automation of tasks such as harvesting, pruning, and planting, Autonomous control and decision-making algorithms for agricultural robots, Human-robot interaction, and collaboration in agricultural settings | 6 Hrs |
| 5 | **Data Analysis and Decision Making in Precision Farming**<br>Introduction to precision farming and data-driven agriculture, Collection, management, and analysis of agricultural data, Machine learning techniques | 6 Hrs |

| | | |
|---|---|---|
| | for crop yield prediction, disease detection, and pest control, Optimization algorithms for resource allocation in precision farming, Integration of robotics and data analytics for intelligent decision making | |
| **6** | **Emerging Trends and Applications in Agricultural Robotics** Advanced technologies in agricultural robotics, such as swarm robotics and soft robotics, Robotic systems for Specific applications like greenhouse farming and livestock management, Integration of Internet of Things (IoT) and robotics in smart agriculture, Regulatory and policy aspects related to agricultural robotics, Prospects, and challenges in the field of agricultural robotics. | 6 Hrs |

**Suggested learning resources:**

**Reference Books:**

1. "Agricultural Field Robotics" by Simon Blackmore, Liu Liu, K. C. Ting, and Wei Zhang
2. "Agricultural Robots: Mechanisms, Controls, and Applications" edited by T. S. Hong, G. S. Virk, and S. Yuta
3. "Agricultural Robots: Emerging Trends and Applications" edited by Sachin Kumar, S. S. Dash, S. Swain, and K. P. Yadav
4. "Robotics and Automation in the Food Industry: Current and Future Technologies" edited by Darwin G. Caldwell, Luca Bascetta, Vittorio Ferrari, and Hoon Soo Lee

**Journals:**

1. Journal of Field Robotics
2. Precision Agriculture
3. Computers and Electronics in Agriculture
4. Biosystems Engineering
5. Journal of Agricultural Engineering Research

## Course: AI based Agriculture (PEC-V)

| **Course Code** | MRAIPEC801-A | **Scheme of Evaluation** | MSE TA& ESE |
|---|---|---|---|
| **Teaching Plan** | **3-0-0-0** | **Mid Semester Exam** | 30 |
| **Credits** | 3 | **Teachers' Assessment** | 20 |
| | | **End Sem Exam** | 50 |

**Course Outcomes:**

Students who successfully complete this course will have an ability to:

1. Explain the significance of agricultural robotics and its role in improving efficiency, productivity, and sustainability in agriculture.
2. Identify key components and subsystems of agricultural robots and understand their integration in real-world applications.
3. Apply image processing and computer vision techniques to monitor crops and estimate yield in agricultural settings.
4. Analyze and make intelligent decisions using data analytics in precision agriculture, integrating robotics and data-driven approaches.

5. Explore emerging trends and technologies in agricultural robotics, such as swarm robotics, soft robotics, and IoT integration.

**Syllabus:**

| Unit | Contents | Lecture |
|---|---|---|
| **1** | **Introduction to AI in Agriculture**<br>Overview of artificial intelligence (AI) and its applications in agriculture, Importance of AI in addressing challenges in farming and food production, Introduction to machine learning, deep learning, and natural language processing, Ethical and social implications of AI in agriculture, Case studies highlighting the impact of AI in the agricultural industry | 6 Hrs |
| **2** | **Data Collection and Analysis in Agriculture**<br>Data sources and collection methods for agricultural data, Preprocessing techniques for cleaning and formatting agricultural data, Exploratory data analysis and visualization in agriculture, Feature selection and engineering for AI models in agriculture, Data-driven decision making in farming practices. | 6 Hrs |
| **3** | **AI Techniques for Crop Monitoring and Disease Detection**<br>Remote sensing and satellite imagery analysis for crop monitoring, Image classification and object detection algorithms for plant disease detection, AI-based methods for pest control and weed management, Prediction models for crop yield estimation and forecasting, Case studies on AI applications in precision agriculture. | 6 Hrs |
| **4** | **AI for Smart Irrigation and Resource Management**<br>AI-driven models for irrigation scheduling and water management, Sensor-based systems for soil moisture monitoring and irrigation optimization, Optimization algorithms for resource allocation in farming operations, AI techniques for nutrient management and fertilizer optimization, Smart farming systems and IoT integration for efficient resource utilization. | 6 Hrs |
| **5** | **Robotics and AI in Agriculture**<br>Integration of AI with robotics for autonomous farming operations, AI-enabled robotic systems for seeding, planting, and harvesting, Machine vision and AI algorithms for crop yield estimation and sorting, Autonomous vehicles and drones for precision agriculture, Challenges and Prospects of AI in agricultural robotics. | 6 Hrs |
| **6** | **AI-Based Decision Support Systems in Agriculture**<br>Development and deployment of AI-based decision support systems, Crop recommendation systems and predictive analytics for farmers, AI models for market analysis and price forecasting, AI-driven supply chain optimization in agriculture, Ethical considerations, and transparency in AI-based decision support. | 6 Hrs |

**Suggested learning resources:**

**Reference Books:**


1. "Artificial Intelligence in Agriculture: A Review" edited by Khin Thida Latt, Naresh Kumar, and Yanbo Huang.
2. "AI for Agriculture: Techniques and Applications" edited by Diego M. Lopez and Emmanuel Jammeh.

3. "Artificial Intelligence for Precision Agriculture" edited by Nicolas Tremblay, Muhammad Abid, and John W. Grove.
4. "Advances in Artificial Intelligence for Agriculture" edited by Leszek Rutkowski and Marcin Korytkowski.
5. "Artificial Intelligence Techniques for Agriculture and Food Quality" edited by G.R. Sinha, P.K. Kapur, and D. Pratap.

**Journals:**

1. Computers and Electronics in Agriculture.
2. Precision Agriculture.
3. Journal of Agricultural Science and Technology.
4. International Journal of Agricultural and Biological Engineering.
5. Computers in Industry: An International Journal.

## Course: Mechatronics for Agriculture(PEC-V)

| **Course Code** | MRAIPEC801-M | **Scheme of Evaluation** | MSE TA& ESE |
|---|---|---|---|
| **Teaching Plan** | **3-0-0-0** | **Mid Semester Exam** | 30 |
| **Credits** | 3 | **Teachers' Assessment** | 20 |
| | | **End Sem Exam** | 50 |

**Course Outcomes:**

Students who successfully complete this course will have an ability to:

1. Do Sensor-Actuator Integration.
2. Implement Control Systems.
3. Study about emerging Technologies

**Syllabus:**

| Unit | Contents | Lecture |
|---|---|---|
| **1** | **Introduction to Mechatronics in Agriculture**<br>Overview of mechatronics and its applications in the agricultural sector, Introduction, agricultural automation and mechanization, Interdisciplinary nature of mechatronics in agriculture, Role of mechatronics in improving productivity, efficiency, and sustainability in farming. | 6 Hrs |
| **2** | **Sensors and Actuators in Agricultural Mechatronics**<br>Fundamentals of sensors and actuators used in agricultural mechatronic systems, Types of sensors for measuring soil parameters, crop health, and environmental conditions, Actuators for mechanized tasks such as irrigation, planting, and spraying, Sensor-actuator integration and interfacing techniques, Calibration and maintenance of sensors and actuators in agricultural applications | 6 Hrs |
| **3** | **Control Systems in Agricultural Mechatronics**<br>Basics of control systems and their applications in agriculture, Feedback, and feedforward control in agricultural mechatronic systems, PID control and other advanced control techniques Modeling and simulation of agricultural systems, Implementation of control algorithms for precision farming | 6 Hrs |
| **4** | **Automation and Robotics in Agriculture** | 6 Hrs |

| | | |
|---|---|---|
| | Introduction to agricultural robots and automation systems, Robotic manipulators for tasks such as harvesting, pruning, and packaging, Automated systems for seed sowing, fertilizer application, and weed control, Navigation and localization algorithms for autonomous agricultural robots, Human-machine interfaces, and interaction in agricultural automation | |
| **5** | **Data Acquisition and Analysis in Precision Agriculture**<br>Data acquisition methods for collecting agricultural data, Sensor networks and wireless communication in precision agriculture, Data analysis and visualization techniques for decision making, Machine learning algorithms for yield prediction and disease detection, Integration of data analytics with mechatronic systems in farming | 6 Hrs |
| **6** | **Emerging Technologies and Future Trends in Agricultural Mechatronics**<br>Advanced technologies in agricultural mechatronics, such as Internet of Things (IoT) and cloud computing, Robotics and automation for smart greenhouse farming Unmanned aerial vehicles (UAVs) and drones for crop monitoring and spraying, Autonomous farming systems and autonomous vehicles in agriculture, Sustainability, and environmental considerations in future agricultural mechatronics | 6 Hrs |

**Suggested learning resources:**


1. "Mechatronics for Agriculture: Opportunities and Challenges" by Subhash Rakheja, Zahurul Islam, and Essam Radwan
2. "Agricultural Mechatronics" edited by Chao Li, Quanmin Zhu, and Xianghui Cao
3. "Mechatronics in Action: Case Studies in Mechatronics - Applications and Education" edited by David Bradley and David Russell
4. "Mechatronics: Principles and Applications" by Godfrey Onwubolu
5. "Mechatronics in Medicine: A Biomedical Engineering Approach" by Jan Paul, Kingshuk Bhattacharya, and Rajnikant V. Patel


**Journals:**

1. Transactions of the ASABE (American Society of Agricultural and Biological Engineers)
2. Computers and Electronics in Agriculture
3. Precision Agriculture
4. Journal of Agricultural Machinery Science
5. Biosystems Engineering

## Course: Agricultural Plant & Device Control (PEC-V)

| **Course Code** | MRAIPEC801-C | **Scheme of Evaluation** | MSE TA& ESE |
|---|---|---|---|
| **Teaching Plan** | **3-0-0-0** | **Mid Semester Exam** | 30 |
| **Credits** | 3 | **Teachers' Assessment** | 20 |
| | | **End Sem Exam** | 50 |

**Course Outcomes:**

Students who successfully complete this course will have an ability to:

1. Understand Agricultural Plant & Device Control.
2. Proficient in Sensors and Actuators for Agricultural Applications.
3. Compete in Measurement and Data Acquisition.
4. Learn advanced Control Techniques and IoT in Agriculture.

**Syllabus:**

| Unit | Contents | Lecture |
|---|---|---|
| **1** | **Introduction to Agricultural Plant & Device Control** Overview of agricultural automation and control systems, Importance and benefits of plant and device control in agriculture, Introduction to plant physiology and its relationship with control system. | 6 Hrs |
| **2** | **Sensors and Actuators for Agricultural Applications** Types and selection of sensors for monitoring plant parameters (e.g., temperature, humidity, light, soil moisture), Actuators for agricultural devices and equipment (e.g., motors, valves, pumps), Integration of sensors and actuators with control systems. | 6 Hrs |
| **3** | **Measurement and Data Acquisition** Principles of measurement and signal conditioning, Data acquisition techniques for plant and device control, Calibration, and accuracy considerations for agricultural measurements | 6 Hrs |
| **4** | **Advanced Control Techniques in Agriculture** Model-based control approaches for plant and device control, Adaptive and predictive control techniques, Optimization, and model-based decision-making for agriculture. | 6 Hrs |
| **5** | **Internet of Things (IoT) in Agricultural Control** IoT concepts and applications in plant and device control, Wireless sensor networks and communication protocols, Cloud-based platforms for data management and remote control. | 6 Hrs |
| **6** | **Data Analysis and Decision Support Systems** Data analysis techniques for plant and device control, Data-driven decision support systems in agriculture, Integration of control systems with farm management software. | 6 Hrs |

**Suggested learning resources:**

**References:**


1. "Automation: The Future of Weed Control in Cropping Systems" by Matthew D. Denton and William C. Hoffmann
2. "Precision Agriculture Technology for Crop Farming" by Ken Sudduth and Robert J. Kitchen
3. "Agricultural Automation: Fundamentals and Practices" by Qin Zhang, Sangjun Lee, and José A. Paredes
4. "Robotics and Automation in the Food Industry: Current and Future Technologies" edited by Darwin G. Caldwell, Luca Bascetta, Vittorio Ferrari, and *Hoon Soo Lee*


**Journals:**

1. Precision Agriculture
2. Biosystems Engineering

3. Journal of Field Robotics
4. Computers and Electronics in Agriculture
5. Journal of Agricultural Engineering Research

## Course: Medical Robotic Technology (PEC-VI)

| Course Code | MRAIPEC802-R | Scheme of Evaluation | MSE TA& ESE |
|---|---|---|---|
| Teaching Plan | 3-0-0-0 | Mid Semester Exam | 30 |
| Credits | 3 | Teachers' Assessment | 20 |
| | | End Sem Exam | 50 |

**Course Outcomes:**

1. Students who successfully complete this course will have an ability to:
2. Identify and describe diverse types of medical robots and their potential applications.
3. Know basic concepts in kinematics, dynamics, and control relevant to medical robotics.
4. Be familiar with the state of the art in applied medical robotics and medical robotics research.
5. Understand the various roles that robotics can play in healthcare.
6. Create a compelling proposal for a new medical robot technology.

**Syllabus:**

| Unit | Contents | Lecture |
|---|---|---|
| 1 | **Introduction to medical robotics:** Overview of the history and evolution of medical robotics., Different classifications of medical robots (surgical, rehabilitation, etc.) and their applications, Introduction to computer-integrated surgery (CIS) and its role in robotic procedures. Applications and paradigms, Surgery for engineers, Interventional radiology for engineers. | 5 Hrs |
| 2 | **Minimally Invasive Surgery (MIS):** Human-machine interfaces, Teleoperation, Cooperative manipulation, Port placement for MIS, Robot design concepts, Video images in MIS, Augmented reality, minimally invasive surgery training. | 5 Hrs |
| 3 | **Image-Guided Interventions:** Medical imaging modalities (e.g., MRI, US, X-ray, CT), Robot compatibility with medical imagers, Image segmentation and modeling, Tracking devices, Frames and transformations, Surgical navigation, Calibration, Rigid and non-rigid registration, Radiosurgery. | 6 Hrs |
| 4 | **Fundamentals of Robot kinematics & Control:** Basic kinematics concepts (forward, inverse, remote center of motion), Kinematic modeling of medical robots used in surgery and interventions. Introduction to robot dynamics and its relevance in medical robotics. Basic control concepts (impedance, admittance),manipulability, workspace analysis. | 5 Hrs |
| 5 | **Fundamentals of Robot Control:** Control theory basics relevant to medical robots (feedback control, motion planning), Design and implementation of control algorithms for surgical tasks, Teleoperation and haptic feedback for robotic surgery. | 5 Hrs |
| 6 | **Current topics in medical robotics (as time permits):** | 10 Hrs |

| | | |
|---|---|---|
| | Existing clinical applications, controversies, and outcomes: Cardiac, abdominal, and urologic procedures with teleoperated robots, Orthopaedic surgery with cooperative robots, Prostate interventions with manual “robots”, Robotic catheters for heart electrophysiology. Mobile robots in the body, Instrument-tissue interaction modeling, Autonomous robotic surgery, other types of healthcare robots: Physically assistive robotics, Socially assistive robotics, Rehabilitation robotics. Emerging trends and advancements in medical robotics research. Applications of medical robots beyond surgery (rehabilitation, drug delivery).Student presentations on proposed novel medical robotic technologies. | |

**Suggested learning resources:**

**Reference Books:**

1. "Medical Robotics: Minimally Invasive Surgery" by Paul S. Agutter and David J. Charnley
2. "Surgical Robotics: Systems, Applications, and Visions" edited by Jacob Rosen, Blake Hannaford, Richard M. Satava
3. "Introduction to Surgical Robotics" by Jaydev P. Desai
4. "Medical Robotics" by Sanjiv Sharma
5. "Robotics in Genitourinary Surgery" edited by Ashok Agarwal, Vipul Patel, Mani Menon

Journals:

1. International Journal of Medical Robotics and Computer Assisted Surgery (IJMRCAS)
2. IEEE Transactions on Robotics and Automation
3. Journal of Medical Robotics Research
4. Annals of Biomedical Engineering
5. Robotics and Computer-Integrated Manufacturing

## Course: AI for Medical Applications (PEC-VI)

| **Course Code** | MRAIPEC802-A | **Scheme of Evaluation** | MSE TA& ESE |
|---|---|---|---|
| **Teaching Plan** | **3-0-0-0** | **Mid Semester Exam** | 30 |
| **Credits** | 3 | **Teachers’ Assessment** | 20 |
| | | **End Sem Exam** | 50 |

**Course Outcomes:**

Students who successfully complete this course will have an ability to:

1. Ethical, Legal, and Social Implications
2. Personalized Medicine
3. Intelligent Systems in Clinical Practice
4. Future Trends and Challenges

**Syllabus:**

| Unit | Contents | Lecture |
|---|---|---|
| **1** | **Foundations:**<br>Introduction to Human and Artificial Intelligence: terminologies, computational models of, intelligence; conceptual frameworks from cognitive and educational psychology, neuroscience, information theory, and linguistics; philosophical foundations of AI, Review of relevant mathematical and statistical concepts: logarithmic loss, cross entropy, optimizing cost functions; linear and logistic regression. | 5 Hrs |
| **2** | **Machine Learning :**<br>Forms of Learning: supervised, semi-supervised, unsupervised, active, and transfer learning, Supervised Learning: (a) Decision trees, non-parametric methods for learning, support vector machines, (b) Bio-inspired Learning (from perceptron to deep learning): neural basis of computing, classical neural networks, deep neural networks, deep belief networks, recurrent neural networks, and convolutional neural networks. Unsupervised Learning: basic and advanced clustering techniques, dimensionality reduction (feature selection and feature extraction) | 7 Hrs |
| **3** | **Knowledge Representation and Reasoning:**<br>Prepositional logic, first-order logic, ontological engineering, probabilistic reasoning, Time-series analysis: temporal models (probabilistic reasoning over time), Emerging paradigms and concepts in artificial social and emotional intelligence | 7 Hrs |
| **4** | **Implementation and Evaluation:**<br>Tools and Technologies for implementing AI methods, Model evaluation and performance metrics, cross-validation, model interpretability, Ethics of AI: bias, fairness, accountability, and transparency in machine learning; Ethical, Legal, and Social Issues of AI in medicine and healthcare | 7 Hrs |
| **5** | **Applications:**<br>Unique characteristics and challenges in medicine and healthcare; History and status quo of intelligent and expert systems in medicine. Risk stratification, patient outcome prediction, disease progression modeling, Clinical decision-making, and intelligent systems to support evidence-based medicine, Phenotype, and clinical/bio-marker discovery, Relevance to personalized medicine, Analysis of tissue morphology and other medical imaging applications | 5 Hrs |
| **6** | **Ethical Considerations and Challenges in AI for Healthcare**<br>Biases in medical data and potential for bias in AI algorithms.<br>Explainability and transparency issues in AI-powered medical decisions.<br>Regulatory frameworks and ethical guidelines for using AI in healthcare.<br>**The Future of AI in Medicine**<br>Emerging trends and advancements in AI for healthcare applications.<br>The role of AI in personalized medicine and robotic surgery.<br>Student presentations on proposed AI solutions for specific medical problems. | 5 Hrs |

**Suggested learning resources:**

**Reference**


1. "Deep Medicine: How Artificial Intelligence Can Make Healthcare Human Again" by Eric Topol

2. "Artificial Intelligence in Medicine: Technical Basis and Clinical Applications" by David J. Marchette
3. "Machine Learning in Medicine: A Complete Overview" by Ton J. Cleophas and Aeilko H. Zwinderman
4. "Artificial Intelligence in Healthcare" edited by Dr. Adam Bohr, Dr. Aditya Jain, Dr. Krishna Chintalapudi, and Dr. Anil Sao

**Journals:**

1. Nature Medicine
2. Journal of the American Medical Informatics Association (JAMIA)
3. Artificial Intelligence in Medicine
4. Journal of Medical Internet Research (JMIR)
5. NPJ Digital Medicine

## Course: Mechatronics for Medical Applications (PEC-VI)

| **Course Code** | MRAIPEC802-M | **Scheme of Evaluation** | MSE TA& ESE |
|---|---|---|---|
| **Teaching Plan** | **3-0-0-0** | **Mid Semester Exam** | 30 |
| **Credits** | 3 | **Teachers' Assessment** | 20 |
| | | **End Sem Exam** | 50 |

**Course Outcomes:**

Students who successfully complete this course will have an ability to:

1. To understand how to measure biochemical parameters and various physiological information.
2. To study the need and technique of electrical safety in Hospitals.
3. To study the use of radiation for diagnostic and therapy.
4. To study about recorders and advanced equipment in medicine

**Syllabus:**

| **Unit** | **Contents** | **Lecture** |
|---|---|---|
| **1** | **Introduction to Mechatronics and Medical Devices**<br>Overview of mechatronics principles and its applications in healthcare. Classification of medical devices and their mechatronic components (e.g., drug delivery systems, prosthetics). Introduction to medical device design and development processes. | 5 Hrs |
| **2** | **Transducers for Bio-Medical Instrumentation**<br>Basic transducer principle Types – source of bioelectric potentials – resistive, inductive, capacitive, fibre- optic, photoelectric and chemical transducers – their description and feature applicable for biomedical instrumentation – Bio and Nano sensors and application | 6 Hrs |
| **3** | **Electronics for Medical Devices** | 7 Hrs |

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|---|---|---|
| | Signal Conditioning, Recording and Display, Input isolation, DC amplifier, power amplifier, and differential amplifier – feedback, op-Amp-electrometer amplifier, carrier Amplifier – instrument power supply. Oscillagraphic – galvanometric, X-Y, magnetic recorder, storage oscilloscopes – electron microscope – PMMC writing systems -Telemetry principles – Bio telemetry. | |
| **4** | **Design and Integration of Mechatronic Systems**<br>Computer-aided design (CAD) tools for medical device design and prototyping. System integration considerations for combining mechanical, electronic, and control elements. Interfacing sensors, actuators, and control systems for medical devices. | 6 Hrs |
| **5** | **Bio-Medical Diagnostic Instrumentation**<br>Introduction – computers in medicine – basis of signal conversion and digital filtering data reduction technique – time and frequency domain technique – ECG Analysis. | 6 Hrs |
| **6** | **Safety, Regulations, and the Future of Medical Mechatronics**<br>Safety standards and regulatory requirements for medical devices (e.g., IEC 60601).Biocompatibility of materials used in medical devices. Emerging trends in medical mechatronics (microfluidics, nanorobotics).Student presentations on proposed novel mechatronic designs for medical applications. | 6 Hrs |

**Suggested learning resources:**

**Reference Books:**


1. "Mechatronics in Medicine: A Biomedical Engineering Approach" by Jan Paul, Kingshuk Bhattacharya, and Rajnikant V. Patel
2. "Introduction to Mechatronics and Measurement Systems" by David G. Alciatore and Michael B. Histand
3. "Robotics and Mechatronics for Medicine and Healthcare" edited by Naohiko Sugita
4. "Mechatronics for Healthcare" by Stephen P. DiBenedetto
5. "Medical Robotics: Principles and Systems" by Frank L. Lewis, Xiaoping Yun, and Chee Kong Chui


**Journals:**

1. IEEE Transactions on Mechatronics
2. Journal of Medical Robotics Research
3. IEEE/ASME Transactions on Mechatronics
4. Biomedical Signal Processing and Control
5. Journal of Healthcare Engineering

## Course: Control for Biomedical Instrumentation systems

| | | | |
|---|---|---|---|
| **Course Code** | MRAIPEC802-C | **Scheme of Evaluation** | MSE TA& ESE |
| **Teaching Plan** | **3-0-0-0** | **Mid Semester Exam** | 30 |
| **Credits** | 3 | **Teachers' Assessment** | 20 |
| | | **End Sem Exam** | 50 |

**Course Outcomes:**

Students who successfully complete this course will have an ability to:

1. Proficiency in Modern Control Theory.

2. Expertise in Smart Sensors for Biomedical Applications.
3. Comprehensive Understanding of Biomechanics.
4. Proficiency in Ultrasonic Applications in Bioengineering.

**Syllabus:**

| Unit | Contents | Lecture |
|---|---|---|
| **1** | **Introduction to Control Systems and Biomedical Instrumentation:** Overview of control systems and their role in biomedical instrumentation. Classification of biomedical systems (physiological, electromechanical) and their control requirements. Examples of control systems in various medical devices (ventilators, pacemakers, drug delivery systems). Transducers: dynamic behaviour, power transducers, driver circuits, pulse generator circuit, piezo generator, piezo sensors, | 6 Hrs |
| **2** | **Modern Control Theory:** State variable representation of linear and nonlinear systems, comparison with transfer function representation, standard forms of representation. Time and frequency domain Specifications, Pole placement by state feedback, controllability and observability, design of observers, and separation principle. Controller design using transfer function approach. Introduction to discrete time control, z transforms, difference equations, analysis of discrete-time systems, controller design in discrete domain | 6 Hrs |
| **3** | **Modeling of Biomedical Systems:** Mathematical modeling techniques for biomedical systems (transfer functions, block diagrams). Examples of modeling physiological systems (cardiovascular, respiratory) and electromechanical devices. Time-domain and frequency-domain analysis of biomedical system models. | 6 Hrs |
| **4** | **Sensors for biomedical application:** Basic transduction principles, Transducers for biomedical applications: Force and pressure transducers: such as piezoelectric, strain gauge, Displacement transducers, and Biopotential Electrodes, list different biopotential signals generated in the human body, Transducers for cardiovascular measurement, Transducers for heart sound measurement, Transducers for Non-invasive diagnostic measurements, Introduction to biomaterials engineering and processing, Properties of materials, Application of materials in medicine, biology, and artificial organs. Piezoelectric ceramics: properties and applications, piezoelectric constants, depolarization: electrical, mechanical, thermal, Time of flight diffraction technique (transit time) measurement, testing of piezo crystal, bonding techniques | 6 Hrs |
| **5** | **Biomechanics:** Introduction to biomechanics, Overview of joints and movements, anatomical levers, Material Characterization of Tissues, Mechanics of Skeletal Muscles, gait, gait parameters Prosthetics and Orthotics, Principles of three-point pressure. Lower limb prostheses, partial weight bearing-PTB socket, total contact-quadrilateral socket, Upper limb prosthesis, Spinal orthoses. Cardiovascular Mechanics: Cardiovascular Physiology, Blood Flow Models, Blood Vessel Mechanics, Heart, Valve Dynamics, Prosthetic Valve Dynamics. | 6 Hrs |
| **6** | **Modeling & Simulations:** | 6 Hrs |

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|---|---|---|
| | Modeling techniques for piezoelectric transducer, Data acquisition techniques Sonography and quantitative measurements such as tissue characterization and typing. Bioeffects and safety for ultrasound, therapeutic applications of high-intensity focused ultrasound. Introduction to control system design software (e.g., MATLAB Simulink) for simulating and analyzing control systems, Case studies of control system design and implementation in specific biomedical applications. | |

**Suggested learning resources:**

**Reference:**

1. "Control Systems for Biomedical Engineering" by Bronzino, Joseph D.
2. "Biomedical Engineering Systems and Technologies: International Joint Conference, BIOSTEC 2008 Funchal, Madeira, Portugal, January 28-31, 2008 Revised Selected Papers" edited by Joaquim Filipe and Ana Fred
3. "Biomedical Signal and Image Processing" by Kayvan Najarian and Robert Splinter
4. "Biomedical Image Analysis: Statistical and Variational Methods" by Milan Sonka, Vaclav Hlavac, and Roger Boyle
5. "Feedback Systems: An Introduction for Scientists and Engineers" by Karl J. Åström and Richard M. Murray

**Journals:**

1. IEEE Transactions on Biomedical Engineering
2. Medical & Biological Engineering & Computing (MBEC)
3. IEEE Control Systems Magazine
4. Biomedical Signal Processing and Control
5. Journal of Medical Engineering & Technology

## Course: Internship / Project

| **Course Code** | MRAIELC803 | **Scheme of Evaluation** | MSE & ESE |
|---|---|---|---|
| **Teaching Plan** | **0-0-16-5** | **Mid Semester Exam** | 50 |
| **Credits** | 8 | **End Sem Exam** | 50 |

**Course Outcomes:**

Students who successfully complete this course will have an ability to:

1. Conceive a problem statement either from rigorous literature survey or from the requirements raised from need analysis.
2. Design, implement and test the prototype/algorithm in order to solve the conceived problem.
3. Improve knowledge and skills by engaging with the project and its various components (research, analysis, design, implementation), students gain knowledge and skills specific to the project topic.
4. Develop project management skills by planning, organization, and time management skills crucial for completing the project.
5. Write a comprehensive report on mini project work.

**Guidelines:**

1. The project is a team activity having 3-4 students in a team. Projects should include mainly Mechanical Engineering but can be multi disciplinary too.

2. The project may be a complete hardware or a combination of hardware and software. The software part in the project should be less than 50% of the total work.
3. Project should cater to a small system required in laboratory or real life.
4. It should encompass components, devices etc. with which functional familiarity is introduced.
5. After interactions with course coordinator and based on comprehensive literature survey/ need analysis, the student shall identify the title and define the aim and objectives of the project.
6. Students are expected to detail out specifications, methodology, resources required, critical issues involved in design and implementation and submit the proposal within the first week of the semester.
7. The student is expected to exert on design, development and testing of the proposed work as per the schedule.
8. Completed project and documentation in the form of project report is to be submitted at the end of semester.

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