गोंय विद्यापीठ
ताळगांव पठार,
गोंय - ४०३ २०६
फोन : + ९१ - ८६६९६०९०४८

Goa University
Taleigao Plateau,Goa - 403 206
Tel : +91-8669609048
Email : registrar@unigoa.ac.in
Website : www.unigoa.ac.in

(Accredited by NAAC with Grade A+)

GU/Acad –PG/BoS -NEP/2026-27/282 Date: 05.08.2026

**CIRCULAR**

Ref. No.: GU/Acad –PG/BoS -NEP/2025/379 dated 08.09.2025

In supersession to the above referred Circular, the syllabus for the Courses offered under specialization **Mechanical and Smart Manufacturing** of **Bachelor of Engineering in Mechanical Engineering** Programme for Semester V to VII, as approved by the Academic Council in its meeting held on 20th February 2026, is attached.

The syllabus for Semester III & IV approved earlier by the Standing Committee of the Academic Council in its meeting held on 24th & 25th July 2025 is also attached.

The Dean, Faculty of Engineering and Principals of affiliated Engineering Colleges are requested to take note of the above and bring the contents of the Circular to the notice of all concerned.

ASHWIN V LAWANDE
Digitally signed by ASHWIN V LAWANDE
Date: 2026.08.05 12:24:44 +05'30'

(Ashwin V. Lawande)
Deputy Registrar – Academic

To,

1. The Dean, Faculty of Engineering, Goa University.
2. The Principals of Affiliated Engineering Colleges.

Copy to:

1. Chairperson, BoS in Mechanical Engineering, Goa University.
2. Controller of Examinations, Goa University.
3. Assistant Registrar Examinations (Technical and Allied), Goa University
4. Directorate of Internal Quality Assurance, Goa University for uploading the Syllabus on the University website.

**Mechanical Engineering**

**Specialization: Mechanical and Smart Manufacturing**

| Sr. No. | Semester | Course Code | Title of the Course | L | T | P | TCr |
|---|---|---|---|---|---|---|---|
| **1** | **III** | **MEC-281** | Additive Manufacturing | 3 | 1 | 0 | 4 |
| **2** | **IV** | **MEC-282** | Industry 4.0 and Industrial Internet of Things | 3 | 0 | 0 | 3 |
| | | **MEC-283** | Industry 4.0 and Industrial Internet of Things Lab | 0 | 0 | 1 | 1 |
| **3** | **V** | **MEC-381** | PLC and SCADA | 3 | 0 | 0 | 3 |
| | | **MEC-382** | PLC and SCADA Lab | 0 | 0 | 1 | 1 |
| **4** | **VI** | **MEC-383** | Introduction to Digital Twin Technology | 3 | 0 | 0 | 3 |
| | | **MEC-384** | Introduction to Digital Twin Technology Lab | 0 | 0 | 1 | 1 |
| **5** | **VII** | **MEC-481** | Artificial Intelligence and Data Science | 3 | 0 | 0 | 3 |
| | | **MEC-482** | Artificial Intelligence and Data Science Lab | 0 | 0 | 1 | 1 |
| | | | **Total** | **15** | **1** | **4** | **20** |

**SEMESTER III**

**Name of the Programme : Mechanical Engineering (Mechanical and Smart Manufacturing)**
**Course Code : MEC-281**
**Title of the course : Additive Manufacturing**
**Number of Credits : 4**
**Effective from AY : 2024-25**

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| **Pre-requisites for the course** | Nil | |
| **Course Objectives** | 1. To provide an overview of the selection of material, equipment, and development of a Rapid Prototype for smart manufacturing in Industry 4.0.<br>2. To Explain the concepts of reverse engineering.<br>3. To provide an overview of the software and design methodology of additive manufacturing | |
| **Units** | Topics | **No of hours** |
| **Unit 1** | **Introduction**: Need-Classification -Additive Manufacturing Technology in Product Development, Materials for Additive Manufacturing Technology, Tooling Applications.<br>Liquid-based and Solid-based additive manufacturing systems: Classification,<br>**Liquid-based system**: Stereolithography Apparatus (SLA) Principle, process, advantages and applications, Digital Light Processing (DLP)- Principle<br>**Solid-based system**: Fused Deposition Modeling –Principle, process, advantages and applications | **15** |
| **Unit 2** | **Powder-based additive manufacturing systems:** Selective Laser Sintering – Principle, Process, advantages and applications, Three-Dimensional Printing –Principle, process, advantages and applications, Laser Engineered Net Shaping (LENS), Electron Beam Melting.<br>**Laminated Object Manufacturing:** Principle of operation, LOM materials, process details, Applications.<br>**Solid Ground Curing:** Principle of operation, Machine details, Applications | **15** |
| **Unit 3** | **Concepts Modelers:** Principle, Thermal jet printer, Laser Engineering Net Shaping (LENS)<br>**Rapid Tooling:** Soft Tooling vs. Hard Tooling, Indirect Rapid tooling -Silicon rubber tooling, Aluminum filled epoxy tooling, Spray metal tooling, Cast Kirksite, 3D Keltool.<br>**Direct Rapid Tooling:** Direct AIM, Quick cast process, Copper | **15** |

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| | polyamide, Rapid Tool DMILS, Sand casting tooling<br>**Rapid manufacturing process optimization:** Factors influencing accuracy, data preparation errors, Part building errors, Errors in finishing, and influence of build orientation. | |
| **Unit 4** | **Software for Additive Manufacturing:** STL files, Overview of Solid view, Magics, Mimics, Magic communicator.<br>**CAD & Reverse Engineering:** Basic Concept, Digitization techniques, Model Reconstruction, Data Processing for Additive Manufacturing Technology<br>CAD model preparation: Part Orientation and support generation, Model Slicing, Tool path Generation. Surface digitizing, surface generation from point cloud, surface modification, data transfer to solid models.<br>**AM Applications**: 3D printing of implants in jaw & face surgery, Prosthetics, Surgical planning & Instruments, Dental applications, Tablet Printing, 3D Bioprinting of tissues & Organ Printing, Automotive & Aerospace applications, 3D printing of a building.<br>**Introduction to 4D and 5D printing**<br>**Note:** Hands on exercises on Additive Manufacturing process and Reverse Engineering with a standard 3 D Printer by slicing STL file to be covered in tutorials | **15** |
| **Pedagogy** | The teaching-learning process shall integrate interactive, reflective, and inquiry-based methods, with a strong emphasis on critical thinking and problem-solving skills. | |
| **References/ Readings:** | **Text Books**<br>1. Paul F. Jacobs, Stereolithography and Other RP & M Technologies,1/e, Society of Manufacturing Engineers in cooperation with the Rapid Prototyping Association of SME, ASME Press, Dearborn, Michigan, 1996, ISBN-10: 0872634671<br>2. Chua C.K., Leong K.F., Lim C.S., Rapid Prototyping: Principles and Applications, Third Edition, World Scientific Publishers, Singapore, 2010, ISBN-13: 978-9812778987<br>3. Liou L.W., Liou F.W., Rapid Prototyping and Engineering Applications: A Toolbox for Prototype Development,1/e, CRC Press, Boca Raton, Florida, 2007, ISBN-13: 978-0849334092 | |
| | **Reference Books**<br>1. I. Gibson, D. Rosen, B. Stucker, Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping and Direct Digital Manufacturing, 1/e, Springer, New York, 2015, ISBN-13: 978-1493921123<br>2. Kamrani A.K., Nasr E.A., Rapid Prototyping: Theory and Practice, 1/e, Springer, New York, 2006, ISBN-13: 978-0387232904 | |

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| **Course Outcomes:** | CO 1. Understand the various processes of additive manufacturing, rapid tooling and reverse engineering<br>CO 2. Apply the knowledge of additive manufacturing, rapid tooling and reverse engineering for engineering applications<br>CO 3. Select the appropriate additive manufacturing and rapid tooling process for a desired application<br>CO 4. Develop simple prototypes using the concepts of computer-aided design and additive manufacturing |

**SEMESTER IV**

**Name of the Programme : Mechanical Engineering (Mechanical and Smart Manufacturing)**
**Course Code : MEC-282**
**Title of the course : Industry 4.0 and Industrial Internet of Things**
**Number of Credits : 3**
**Effective from AY : 2024-25**

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| **Pre-requisites for the course** | Nil | |
| **Course Objectives** | 1. To Understand the fundamental concepts of Industry 4.0<br>2. To provide an overview of Industrial Internet of Things (IIoT) and its communication models used to develop smart industrial applications.<br>3. To provide an overview of various cybersecurity threats, challenges in IIoT security, and their impact on industrial automation.<br>4. To Understand the role of Artificial Intelligence (AI), Machine Learning (ML), Big Data Analytics, and Cloud Computing in Industry 4.0 | |
| **Units** | Topics | **No of hours** |
| **Unit 1** | **Introduction to Industry 4.0** – Fourth Industrial Revolution, Definition and Digital Megatrends in Industry 4.0, Design principles, Digital twin, Smart Factory, PLM for Industry 4.0<br>**Industrial Internet of Things (IIoT):** Definition of IoT, IoT functional blocks, IoT communication models, Levels of IoT, Wireless sensor networks, Introduction to cyber-physical systems, Smart sensor, Intelligent sensor, 5C architecture for cyber-physical systems, Introduction to M2M communication, IIOT layer-wise architecture | **11** |
| **Unit 2** | **Communication in Industry 4.0:** - IEEE 802.15.4, Zigbee, Z wave, Bluetooth, RFID, MQTT, Basics of 5G and API<br>**Domain-specific IoTs:** Smoke/gas detector, Smart parking, Remote vehicle diagnostics, Machine diagnosis & prognosis, Indoor air quality monitoring, Wearable electronics, Smart vending machine<br>**Cybersecurity:** Hacking, Common threats: Malware, Ransomware, Phishing, Social engineering<br>**Cybersecurity in IIoT:** Purpose, Elements protected, Components of cybersecurity, Requirements of cybersecurity & IIoT security standards<br>**Virtual Reality (VR) and Augmented Reality (AR):** Introduction, Features, Applications, Types of AR & VR | **11** |
| **Unit 3** | **Big Data Analytics:** Classification of digital data, Introduction to big data, Definition, Characteristics of big data, Data sources, | **11** |

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| | Typical data warehouse environment and Hadoop environment, Introduction to Big data analytics, Big data analytics for Industry 4.0, Types of analytics<br>**Data exploration:** Data pre-processing, Data Quality, Data cleaning- Missing values, Binning, outliers, Data cleaning process, Data reduction- Dimensionality and numerosity reduction, Sampling, Data compression, Brief overview of data transformation strategies and data integration, Normalization, Data visualization- Relationship between features, Scatter plot, bar plots, histogram, box plots | |
| **Unit 4** | **Artificial Intelligence and Machine Learning:** Introduction, Scope, Machine learning, Role of AI in Industry 4.0 & IIoT, Types of ML algorithms-, Supervised and unsupervised learning, Clustering, Regression model Collaborative filtering, Association rule mining, Decision tree, applications of IIoT with ML<br>**Cloud computing in IIoT:** Introduction, Need for cloud, Cloud components, Full and para virtualization, Cloud deployment models, Services, Applications, Cloud based IIoT architecture, Cloud of Things, Introduction to Google cloud platform and Amazon web services, Fog computing<br>**IIoT Case studies:** IIoT processing for self-driving car, IoT system for weather monitoring | **12** |
| **Pedagogy** | The teaching-learning process shall integrate interactive, reflective, and inquiry-based methods, with a strong emphasis on critical thinking and problem-solving skills. | |
| **References/Readings:** | **Text Books**<br>1. S. Misra, C. Roy, A. Mukherjee, Introduction to Industrial Internet of Things and Industry 4.0, 1/e, CRC Press, Boca Raton, Florida, 2020, ISBN-13: 978-0367460712<br>2. Jiawei Han, Micheline Kamber, Jian Pei, Data Mining: Concepts and Techniques, 3rd Edition, Elsevier, Amsterdam, 2011, ISBN-13: 978-0123814791<br>3. A. Bahga, V. Madisetti, Internet of Things: A Hands-On Approach, 1st Edition, CreateSpace Independent Publishing Platform, Scotts Valley, California, 2014, ISBN-13: 978-0996025515 | |
| **References/ Readings:** | **Reference Books**<br>1. Alasdair Gilchrist, Industry 4.0: The Industrial Internet of Things, 1st Edition, Apress, New York, 2016, ISBN: 1484220467<br>2. S. Misra, A. Mukherjee, A. Roy, Introduction to IoT, 1/e, Cambridge University Press, Cambridge, 2020, ISBN: 9781108842952 | |
| **Course Outcomes:** | CO 1. Understand the technologies like Cyber-Physical Systems, Internet of Things, Data Analytics, Cloud Computing, and Machine Learning that drive Industry 4.0 | |

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| | CO 2. Apply concepts of data analytics and machine learning for simple real-life applications<br>CO 3. Analyze Industrial IoT based applications<br>CO 4. Analyze Industry 4.0 tool integration for optimized smart manufacturing |

**Name of the Programme** : **Mechanical Engineering (Mechanical and Smart Manufacturing)**
**Course Code** : **MEC-283**
**Title of the course** : **Industry 4.0 and Industrial Internet of Things Lab**
**Number of Credits** : **1**
**Effective from AY** : **2024-25**

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| **Pre-requisites for the course** | Nil | |
| **Course Objectives** | 1. To Understand the basics of IIoT and AI/ML, including microcontroller programming and sensor-actuator interfacing.<br>2. To provide an Overview of using Arduino, Raspberry Pi, and NodeMCU for data acquisition, visualization, and cloud integration.<br>3. To Understand AI/ML models using Python/R for data preprocessing and regression.<br>4. To provide an overview of Automated processes, sending alerts, and enabling smart decision-making using IIOT | |
| **List of Experiments** | | **No of hours** |
| | 1. Modules and Sensors Interfacing (LM35, DHT 11, POT, IR sensor, Ultrasonic sensors) using Arduino/Raspberry Pi/NodeMCU<br>2. Modules and Actuators Interfacing (Relay, Motor, Buzzer) using Arduino/Raspberry Pi/Node MCU<br>3. Visualization of diverse sensor data using dashboard (part of IoT's 'control panel')<br>4. Write a program to interface Push button/Digital sensor (IR/LDR) and to turn ON LED /Buzzer for 1 sec after every 2 seconds.<br>5. Write a program to interface OLED with Arduino/Raspberry Pi and write a program to print temperature and humidity readings on it.<br>6. To interface Bluetooth with Arduino/Raspberry Pi and write a program to send sensor data to smartphone using Bluetooth<br>7. Write a program on Arduino/Raspberry Pi/Node MCU to upload & retrieve temperature and humidity data from cloud.<br>8. Introduction to Python & ML Libraries<br>9. To perform data preprocessing and cleaning techniques for preparing raw data for analysis<br>10. To implement and evaluate linear/multiple regression models for predictive analysis | **30** |

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| **Pedagogy** | The teaching-learning process shall combine instructional learning, constructive thinking, inquiry-based and collaborative learning, experiential learning, and problem-solving approaches. |
| **Course Outcomes:** | CO 1. Demonstrate the ability to interface sensors, actuators, and communication modules with IIoT devices.<br>CO 2. Implement real-time data acquisition and visualization using dashboards and cloud storage.<br>CO 3. Develop Python-based AI/ML models for analyzing and predicting sensor data trends.<br>CO 4. Design an IIoT system for automation and smart monitoring applications. |

**Semester V**

**Name of the Programme : Mechanical Engineering (Mechanical and Smart Manufacturing)**
**Course Code : MEC-381**
**Title of the Course : PLC and SCADA**
**Number of Credits : 3**
**Effective from AY : 2024-25**

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| **Pre-requisites for the course** | Nil | |
| **Course Objectives:** | **The course will enable students to:**<br>1. Introduce the fundamentals of PLC hardware, architecture, and system organization.<br>2. Develop the ability to write PLC programs using basic logic, timers, and counters.<br>3. Familiarize students with PLC networking concepts and SCADA system architecture used in industrial automation.<br>4. To apply PLC and SCADA concepts in industrial automation systems. | |
| | | **No of hours** |
| **Unit - 1** | Introduction to PLC: History and Evolution of PLC, PLC Advantages and Disadvantages, Overall PLC system.<br>PLC Hardware: PLC Architecture and Block Diagram. Central Processing Unit, Solid State Memory, I/O modules (interfaces), Power supplies | **10** |
| **Unit - 2** | PLC Programming: electrical wiring diagram, scan cycle. Programming languages for PLC.<br>PLC module addressing, registers basics, basic relay instructions,<br>Digital Logic Gates, Boolean Algebra PLC programming , Concept of Latching, Master-Slave, Interlocking.<br>Arithmetic functions, Comparison functions, data handling, data move functions, | **12** |
| **Unit - 3** | Timers: Mechanical Timing relay, Timer instructions, ON delay timer instruction, Off-Delay timer instruction, Retentive Timer, Cascading Timers, examples of timer function industrial application; industrial process timing application.<br>Counters: Counter Instructions, Up-counter, down counter, UpDown counter, Cascading counters, Incremental encoder counter applications, Combining counter and timer functions, High Speed counter instruction, examples of counter function industrial application. | **11** |

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| **Unit - 4** | PLC Networking: Introduction to Industrial Control Hierarchy (Field level, Control level, Supervisory level). Need for Networking in Automation Systems. Basic Concepts of Industrial Communication Networks. Overview of Common Industrial Networks:Modbus, Profibus, DeviceNet, CAN-based networks, Industrial Ethernet.<br>SCADA Systems: Introduction to SCADA and its role in industrial automation. Architecture and components of SCADA systems.<br>Functions of SCADA: Data acquisition, monitoring, control, alarms, and data logging. Introduction to RTU and PLC as SCADA field devices. Basics of Human Machine Interface (HMI). Applications of SCADA in process and manufacturing industries. | **11** |
| **Pedagogy:** | The teaching-learning process shall integrate interactive, reflective, and inquiry-based methods, with a strong emphasis on critical thinking and problem-solving skills. | |
| **References/ Readings:** | **Textbooks**<br>1. John W. Webb, Ronald A. Reis; Programmable Logic Controllers: Principles and Applications; 5th Edition, Prentice Hall of India Pvt. Ltd., 2002. (ISBN-13: 9788120323087.)<br>2. Frank D. Petruzella; Programmable Logic Controllers; 5th Edition, McGraw-Hill; 2016.( ISBN-13: 9780073373843.)<br>3. Madhuchhanda Mitra, Samarjit Sengupta; Programmable Logic Controllers: Industrial Automation — An Introduction; 2nd Edition, Penram International Publishing Pvt. Ltd., 2017. (ISBN-13: 9788187972631.)<br>4. Stuart A. Boyer; SCADA: Supervisory Control and Data Acquisition; 4th Edition, ISA Publications, 2009/2010. (ISBN-13: 9781936007097.)<br>5. J. R. Hackworth, F. D. Hackworth; Programmable Logic Controllers: Programming Methods and Applications; Pearson; 2003. (ISBN-13: 9780130607188.)<br>**References**<br>1. Jitender Singh, Monika Deswal; PLC and SCADA; Laxmi / USP (India) (1st Edition), 2016. (ISBN-13: 9789385935398.)<br>2. Gary Dunning; Introduction to Programmable Logic Controllers; 3rd Edition, Thomson/Delmar Learning, 2005. (ISBN-13: 9781401884260.)<br>3. Jon Stenerson; Industrial Automation and Process Control; Pearson, 2002. (ISBN-13: 9780130330307) | |
| **Course Outcomes:** | CO 1. Explain the architecture, hardware components, and operation of PLC systems.<br>CO 2. Apply PLC programming concepts to implement logic, arithmetic, timer, and counter-based control functions. | |

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| | CO 3. Analyze PLC programs for sequencing, interlocking, and industrial control applications.<br>CO 4. Explain PLC networking concepts and the role of SCADA systems in industrial automation. |

**Name of the Programme** : **Mechanical Engineering ( Mechanical and Smart Manufacturing)**
**Course Code** : **MEC-382**
**Title of the Course** : **PLC and SCADA Lab**
**Number of Credits** : **1**
**Effective from AY** : **2024-25**

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| **Pre-requisites for the course** | Nil | |
| **Course Objectives:** | **The course will enable students to:**<br>1. Familiarize students with basic PLC programming concepts and logic implementation.<br>2. Develop the ability to implement control logic using timers, counters, and arithmetic functions.<br>3. Introduce sequencing and basic process control using PLC and SCADA systems.<br>4. Enable students to design and troubleshoot PLC–SCADA control applications | |
| | **LIST OF EXPERIMENTS** | **No. of Hours** |
| | 1. Design and Implementation of Basic Logic Gates Using PLC<br>2. Implementation of Boolean Logic Expressions Using PLC Programming<br>3. Development of Latching, Start–Stop, and Jog Control Circuits<br>4. Design and Implementation of Interlocking Control Logic<br>5. Implementation of Timer-Based Control Applications<br>6. Design and Implementation of Counter-Based Control Systems<br>7. Implementation of Comparison Functions in PLC-Based Control<br>8. Design and Implementation of Arithmetic Operations Using PLC<br>9. Sequencing and Control of Pneumatic Cylinders Using Timers<br>10. Monitoring and Control of Temperature / Pressure Parameters Using SCADA | **30** |
| **Pedagogy:** | The teaching-learning process shall combine instructional learning, constructive thinking, inquiry-based and collaborative learning, experiential learning, and problem-solving approaches. | |
| **Course Outcomes:** | CO 1. Apply PLC programming concepts to implement logic gates, Boolean expressions, and basic control functions.<br>CO 2. Implement and analyze PLC-based control logic using timers, counters, interlocking, and sequencing operations<br>CO 3. Apply PLC and SCADA tools to monitor and control simple industrial processes such as pneumatic sequencing and | |

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| | temperature/pressure control.<br>CO 4. Design, test, and troubleshoot PLC–SCADA based control programs for simple industrial automation applications. |

**SEMESTER VI**

**Name of the Programme : Mechanical Engineering (Mechanical and Smart Manufacturing)**
**Course Code : MEC-383**
**Title of the Course : Introduction to Digital Twin Technology**
**Number of Credits : 3**
**Effective from AY : 2024-25**

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| **Pre-requisites for the course:** | Industry 4.0 and Industrial Internet of Things | |
| **Course Objectives:** | **The course will enable students to:**<br>1. Provide an overview of the basic concepts of digital twin and the enabling technologies for digital twin.<br>2. Explain the architecture, hardware, software, and key technologies of Virtual and Augmented Reality systems for interactive and immersive applications.<br>3. Introduce digital twin development methods, platforms, and their integration with IoT, AI, and enterprise systems for smart industrial applications.<br>4. Understand industrial use cases and applications of digital twin, VR, and AR technologies | |
| | | **No of hours** |
| **Unit - 1** | **Introduction and Key Concepts of Digital Twins in Industry 4.0:** Introduction to digital twin, Basic concepts, Product & process digital twins, Digital model, Digital shadow, Digital twin prototype, Digital twin instance, Digital twin aggregate, Partial digital twin, Clone digital twin, Augmented digital twin, Digital threads, Types of digital twin, Data Flow in digital twin, Smart and connected design, Accelerating industry 4.0 using digital twin<br>**Digital Twin Development, Platforms, and Smart Industrial Applications:** Steps in building digital twin, Integration of IOT & CAD, Integration of IOT, BIM data and machine learning, Hardware and software related to digital twin, Working of a digital twin, Digital twin platforms, Concurrent engineering and digital twin, Digital twin as a smart service to industries. | **11** |
| **Unit - 2** | **Digital Twin Networks, Modelling, and Applications**: Digital Features, and Visions, DT Modelling Methods, DT Networks (DTNs), DTN concepts, DTN Communications, DTN Applications, Artificial Intelligence in Digital Twin<br>**Use cases of Digital Twin:** Product development, Logistics, Manufacturing, Predictive Maintenance, Facility Management, | **11** |

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| | Simulation, Process Industry<br>**Integration of Digital Twin:** Product Life Cycle Management (PLM), Big Data Analytics, Enterprise Resource Planning (ERP), Manufacturing Execution Systems (MES) | |
| **Unit - 3** | **Virtual Reality Concepts and Devices:** Architecture of VR systems, VR hardware: VR input hardware- Tracking systems, Motion capture systems, Data gloves, VR output hardware- Visual displays, Brief overview of Perception, 3D Interaction and Manipulation, and Tracking technologies in VR<br>**Stereoscopy:** Definition, Basic Concepts of Parallax, Free viewing, Polarization systems, Shutter system, Holography, Real-Time Rendering<br>**VR Software:** Overview of Unity, Google AR & VR, and Unreal Engine | **12** |
| **Unit - 4** | **Augmented Reality System Structure**: User, Interaction, device, virtual content, tracking<br>**Key Technology in Augmented Reality**: Intelligent display technology, 3D registration technology, Intelligent interaction technology, Integration with digital twin<br>**AR Software**: Types, Trends, Marker-based applications, Location-based applications, 3D recognition and tracking, SLAM, Overview of Vuforia, Marker-based Augmented Reality**.** | **11** |
| **Pedagogy:** | The course uses conceptual lectures, hands-on exercises, and case studies to teach digital twins, VR, and AR, enabling students to model, simulate, and apply these technologies in Industry 4.0 environments. | |
| **References/ Readings:** | **Textbooks**<br>1. Fei Tao, Meng Zhang, A. Y. C. Nee; Digital Twin Driven Smart Manufacturing, Elsevier, 2025.(ISBN: 978-0-443-15423-4)<br>2. Yan Zhang; Digital Twin Architectures, Networks, and Applications, Springer, 2023. (ISBN: 978-3-031-24353-7)<br>3. Daniel, Srinivasan Sriramulu, N. Partheeban, Santhosh Jayagopalan; Digital Twin Technology and Applications, Auerbach Publications (CRC Press), 2024. (ISBN: 978-1-032-40641-8)<br>4. Zhihan Lyu (Ed.); Handbook of Digital Twins, CRC Press, 2024. (ISBN: 978-1-032-39146-2)<br>5. G. C. Burdea, P. Coiffet; Virtual Reality Technology, 2nd Edition, Wiley–IEEE Press, 2003 . (ISBN: 978-0-471-36089-6)<br>6. Alan Craig, William Sherman, Jeffrey Will; Developing Virtual Reality Applications: Foundations of Effective Design, Morgan Kaufmann, 2009. (ISBN: 978-0-12-374943-7)<br>**References** | |

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|---|---|
| | 1. Maryam Farsi, Alireza Daneshkhah, Amin Hosseinian-Far, Hamid Jahankahani; Digital Twin Technologies and Smart Cities, Springer. (ISBN: 978-3-030-98644-3)<br>2. George Mather; Foundations of Sensation and Perception, 2nd Edition, Psychology Press, 2009. (ISBN: 978-1841697149)<br>3. Sumit Badotra, Sarvesh Tanwar, Ajay Rana, Nidhi Sindhwani, Ramani Kannan (Eds.); Handbook of Augmented and Virtual Reality, De Gruyter, 2023. (ISBN: 978-3110773437)<br>4. Steve Aukstaklis; Practical Augmented Reality: A Guide to the Technologies, Applications, and Human Factors for AR and VR, Addison-Wesley, 2017. (ISBN: 978-0134094231) |
| **Course Outcomes:** | CO 1. Understand the fundamental concepts, architecture, and components of Digital Twin, Virtual Reality, and Augmented Reality systems and their significance in Industry 4.0.<br>CO 2. Apply modelling and simulation techniques involving IoT, AI, CAD, and real-time rendering in digital twin and AR/VR environments.<br>CO 3. Analyze the hardware, software, and communication frameworks of Digital Twin Networks, VR/AR systems, and their interoperability with industrial platforms such as PLM, ERP, and MES.<br>CO 4. Develop Digital Twin, VR, and AR applications by applying the principles of tracking, motion capture, and rendering |

**Name of the Programme** : **Mechanical Engineering (Mechanical and Smart Manufacturing)**
**Course Code** : **MEC-384**
**Title of the Course** : **Introduction to Digital Twin Technology Lab**
**Number of Credits** : **1**
**Effective from AY** : **2024-25**

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| **Pre-requisites for the course:** | Industry 4.0 and Industrial Internet of Things | |
| **Course Objectives:** | **The course will enable students to:**<br>1. To develop practical skills in modeling, simulating, and analyzing digital twins of industrial systems.<br>2. To provide hands-on experience with VR/AR technologies for visualizing and interacting with virtual environments.<br>3. Introduce simulation-based analysis of structural, modal, and thermal behaviour of engineering systems using appropriate software tools.<br>4. Understand integrated digital twin, simulation, and VR/AR workflows for industrial and engineering applications. | |
| | **LIST OF EXPERIMENTS** | **No. of Hours** |
| | **I. Digital Twin**<br>Software: Anylogic<br>1. Introduction to Anylogic GUI<br>2. Job shop model<br>3. Wind turbine maintenance model<br>4. Supply chain GIS model<br>5. Air defense system model<br>**II. VR/AR**<br>6. Demonstration of VR technology using standard headsets to experience immersive environments, interact with virtual objects<br>7. Demonstration of Augmented Reality using mobile devices and/or AR head-mounted displays to overlay virtual content onto the real-world environment<br>**III. Simulation**<br>**Software: ANSYS**<br>8. Structural analysis<br>9. Modal analysis<br>10. Thermal analysis | **30** |
| **Pedagogy:** | The course uses hands-on simulations and VR/AR demonstrations to teach how to model, visualize, and analyze industrial systems with Digital twin and Engineering tools. | |

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| **References** | https://www.anylogic.com |
| **Course Outcomes:** | CO 1. Build and simulate digital twin models for industrial applications<br>CO 2. Visualize and interact with virtual and augmented reality environments to understand immersive design concepts.<br>CO 3. Perform engineering simulations including structural, modal and thermal analyses.<br>CO 4. Integrate digital twin models, VR/AR visualization, and engineering simulation results for analysis and decision-making in industrial applications |

**SEMESTER VII**

**Name of the Programme : Mechanical Engineering (Mechanical and Smart Manufacturing)**
**Course Code : MEC-481**
**Title of the Course : Artificial Intelligence and Data Science**
**Number of Credits : 3**
**Effective from AY : 2024-25**

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| **Pre-requisites for the course:** | Industry 4.0 and Industrial Internet of Things | |
| **Course Objectives:** | **The course will enable students to:**<br>1. Introduce data analytics concepts, data types, and big data processing frameworks.<br>2. Understand data stream mining and real-time analytics using modern platforms.<br>3. Explain core artificial intelligence concepts, problem-solving methods, and reasoning under uncertainty.<br>4. Introduce machine learning techniques and their applications in data analysis and intelligent systems. | |
| | | **No of hours** |
| **Unit – 1** | **Data Analytics:** Labelled and unlabeled data, Types of data, Data storage and representation, Grid and cluster computing, Big data analysis framework, Datasets and data types, Heat map.<br>**Data Stream Mining and Real Time Analytics:** Data stream concepts, model and architecture, Types of data streams and sources, Stream computing, Sampling data in a stream, Filtering of stream, Counting distinct elements in a stream, Estimating moments, Counting of 1's in a window, Decaying windows, Real time analytics platform (RTAP): Spark Streaming, RTAP Application in real-time sentiment analysis using tweets and stock market predictions.<br>**Big Data technology Landscape:**<br>**NoSQL:** Overview and applications**,** Types of NoSQL databases, Features, Advantages, Use in Industry<br>**Hadoop:** Features, advantages, versions, Overview of Hadoop Ecosystem: Components for data ingestion, data processing, and data analysis | **12** |
| **Unit – 2** | **Artificial Intelligence: Intelligent Agents**: Agents and environment, Specifying the task environment, Classification of task environment, Rational, Simple reflex, Model-based reflex, goal-based, utility-based, learning and agents | **11** |

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| | **Problem Solving:** Problem-solving agents, Real-world problems, Uninformed **search strategies**: Breadth-first search, Depth-first search, Uniform cost search, Depth-limited search, Iterative Deepening depth-first search, Bidirectional search, **Informed search strategies**: Greedy Best-First Search, A* search<br>**Uncertainty:** Definition, Sources, Bayes' rule, Belief network. | |
| **Unit - 3** | **Machine Learning**: Applications, Supervised learning, Classification, Unsupervised learning, Dimensionality reduction, Semi-supervised and reinforcement learning, Instance-based & model-based learning, Machine learning challenges and process<br>**Instance-based learning algorithms:** k-nearest neighbor, Weighted k- nearest neighbour, Nearest centroid classifier, Simple numericals<br>**Regression Analysis:** Types of regression models, Introduction to linear regression, Validation of regression models, Introduction to multiple linear regression, Simple numericals, | **12** |
| **Unit – 4** | **Model-Based learning**: Structure of a decision tree, Simple exercises, Support vector machine (Basic concept only)<br>**Clustering algorithms:** Introduction to clustering approaches, Proximity measures, Simple numericals, K-means clustering (Basic concept only)<br>**Artificial Neural Network:** Structure, Types of ANN<br>**Object recognition:** Introduction, Applications, brightness & feature-based recognition, Using vision for manipulation and navigation<br>**Brief overview of Edge AI and AIoT** | **10** |
| **Pedagogy:** | The course employs a blend of conceptual teaching, hands-on exercises, and case-based learning to integrate AI and Data Science techniques with real-world smart manufacturing applications. | |
| **References/ Readings:** | **Textbooks**<br>1. Raj Kamal, Preeti Saxena, Big Data Analytics, 1st Edition, McGraw Hill Education (India) Pvt. Ltd., New Delhi, India, 2024.(ISBN-13: 978-9357051235.)<br>2. Seema Acharya, Subhashini Chellappan, Big Data Analytics, 2nd Edition, John Wiley & Sons, Hoboken, USA, 2019.(ISBN-13: 978-1119557593.)<br>3. Stuart Russell, Peter Norvig, Artificial Intelligence: A Modern Approach, 3rd Edition, Prentice Hall, Upper Saddle River, USA, 2016.(ISBN-13: 978-0136042594.)<br>4. S. Sridhar, M. Vijayalaksmi, Machine Learning, 1st Edition, Oxford University Press, New Delhi, India, 2021.(ISBN-13: 978-0190123431.)<br>**References** | |

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| | 1. Jiawei Han, Micheline Kamber, Jan Pei, Data Mining: Concepts and Techniques, 3rd Edition, Elsevier, 2012. (ISBN-13: 978-0123814791.)<br>2. Deepak Khemani, A First Course in Artificial Intelligence, 1st Edition, McGraw-Hill Education (India), New Delhi, India, 2013. (ISBN-13: 978-0071329927.)<br>3. John D. Kelleher, Brian Mac Namee, Aoife D'Arcy, Fundamentals of Machine Learning for Predictive Data Analytics: Algorithms, Worked Examples, and Case Studies, 1st Edition, MIT Press, Cambridge, USA, 2015. (ISBN-13: 978-0262028189.)<br>4. M. Gopal, Applied Machine Learning, 2nd Edition, McGraw Hill Education (India) Pvt. Ltd., New Delhi, India, 2018. (ISBN-13: 978-9389583301.) |
| **Course Outcomes:** | CO 1. Understand the fundamentals of Artificial Intelligence, Data Analytics, and Machine Learning concepts used for intelligent problem solving and data interpretation.<br>CO 2. Apply AI search methods, data analytics techniques, and machine learning algorithms to real-world datasets.<br>CO 3. Analyze the interrelation of AI, ML, and data analytics techniques for real-time applications in prediction, pattern recognition, and decision support.<br>CO 4. Implement data-driven techniques to solve simple real-world problems and model intelligent agents and learning systems. |

**Name of the Programme** : **Mechanical Engineering (Mechanical and Smart Manufacturing)**
**Course Code** : **MEC-482**
**Title of the Course** : **Artificial Intelligence and Data Science lab**
**Number of Credits** : **1**
**Effective from AY** : **2024-25**

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| **Pre-requisites for the course** | Industry 4.0 and Industrial Internet of Things | |
| **Course Objectives:** | **The course will enable students to:**<br>1. Introduce data visualization techniques using Python/R for effective data interpretation.<br>2. Understand fundamental artificial intelligence search algorithms through programming.<br>3. Apply machine learning algorithms for prediction and classification problems.<br>4. Introduce basic machine vision concepts for image processing and object recognition. | |
| | **LIST OF EXPERIMENTS** | **No. of Hours** |
| | Tools: Python/ R programming<br>**I. Data Visualisation using Matplotlib and Seaborn**<br>1. Program to display a histogram showing the number of employees in specific age groups.<br>2. Program to display a pie chart showing percentage of expenditures in each department of a company<br>3. Program to display 3 different plots as subplots in a grid of 2 rows and 3 columns<br>**II. Artificial Intelligence**<br>1. Program to implement Breadth First Search algorithm<br>2. Program to implement Depth First Search algorithm<br>3. Program to implement Uniform Cost Search algorithm<br>**III. Machine Learning**<br>1. Program to find the per capita income of a country based on data provided using simple linear regression.<br>2. Program to predict prices of homes using multiple linear regression.<br>3. Program to predict whether a patient is diabetic using KNN model.<br>**IV. Machine vision**<br>1. Exercise on image processing, feature extraction and object recognition | **30** |
| **Pedagogy:** | The course uses a hands-on, and experiential learning approach, | |

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| | combining coding exercises, data visualization tasks, algorithm implementation, machine learning modeling, and computer vision to develop practical skills in AI and Data Science for smart manufacturing applications. |
| **References** | 1. R. Nageswara Rao, Machine Learning in Data Science using Python, 1st Edition, Dreamtech Press, New Delhi, India, 2024. (ISBN-13: 978-9351196345.)<br>2. Prateek Joshi, Artificial Intelligence with Python, 1st Edition, Packt Publishing, Birmingham, UK, 2017. (ISBN-13: 978-1786464392.) |
| **Course Outcomes:** | CO 1. Visualize and interpret data effectively using Matplotlib and Seaborn, including histograms, pie charts, and multi-plot grids.<br>CO 2. Implement classical AI search algorithms such as BFS, DFS, and Uniform Cost Search to solve real-world problem scenarios.<br>CO 3. Build machine learning models for regression and classification tasks using datasets, including prediction of income, housing prices, and medical diagnostics.<br>CO 4. Perform basic computer vision tasks, including image processing, feature extraction, and object recognition for smart manufacturing applications. |