M.TECH PROGRAMME

MANUFACTURING AND AUTOMATION

CURRICULUM & SYLLABUS

DEPARTMENT OF MECHANICAL ENGINEERING

2024 Admission onwards

M.Tech Manufacturing and Automation

Introduction

Newer Industrial revolutions changed the way companies manufacture, improve, and distribute their products. Manufacturers are integrating new technologies, including Internet of Things (IoT), digital twins, cyber physical systems, and AI and machine learning into their production facilities and throughout their operations. The smart factories are equipped with advanced sensors, embedded software and robotics that collect and analyze data and allow for better decision making. These digital technologies lead to increased automation, predictive maintenance, self-optimization of process improvements and, above all, a new level of efficiency and responsiveness to customers which were not previously possible.

The program in manufacturing and automation provides an in depth understanding of wide range of domains like advanced manufacturing processes, additive manufacturing, process automation, virtual instrumentation, sustainable manufacturing, lean manufacturing, Internet of things, machine learning and AI driven smart factory concepts which helps the graduates to develop their skills to suit the current industrial needs and competitiveness.

Program Objective

Analyze and apply the acquired knowledge in engineering principles, automation technologies and artificial intelligence to model and develop sustainable, green & efficient automation systems for manufacturing.

Vision of the Institute

To be a global leader in the delivery of engineering education, transforming individuals to become creative, innovative, and socially responsible contributors in their professions.

Mission of the Institute

- To provide best-in-class infrastructure and resources to achieve excellence in technical education
- To promote knowledge development in thematic research areas that have a positive impact on society, both nationally and globally
- To design and maintain the highest quality education through active engagement with all stakeholders – students, faculty, industry, alumni and reputed academic institutions
- To contribute to the quality enhancement of the local and global education ecosystem
- To promote a culture of collaboration that allows creativity, innovation, and entrepreneurship to flourish, and
- To practice and promote high standards of professional ethics, transparency, and accountability.

Vision of the Department

To transform our students into outstanding mechanical engineers with strong domain knowledge and skills, society-centric research intent, and exemplary ethical values, making them the most desired professionals by research institutions, industry and society.

Mission of the Department

- To develop in each student, a profound understanding of fundamentals, motivation for continuous learning, and practical problem-solving skills for building a successful career.
- To create and share technical knowledge and collaborate with industry and institutions for the betterment of society.
- To imbibe ethical values, leadership qualities and entrepreneurial skills in students.
- To sustain a conducive environment to involve students and faculty in research and development.

Program Educational Outcomes (PEOs)

PEO1: Develop and implement innovative methods and models for improving the performance of manufacturing systems

PEO2: Apply smart manufacturing concepts for enhancing manufacturing and supply chain operations

PEO3: Conduct research by following ethical practices with intellectual integrity to provide cost-effective and sustainable solutions for industrial and societal problems

PEO4: Collaborate and function effectively as an individual and team member in a professional career and/or entrepreneurship

Mission Statement - PEO Mapping

Mapping	M1	M2	M3	M4
PEO1	3	3	1	2
PEO2	3	3	1	1
PEO3	1	1	1	3
PEO4	1	1	2	2

Program Outcomes (POs)

PO1: Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor's program

PO2: An ability to write and present a substantial technical report/document.

PO3: An ability to independently carry out research/investigation and development work to solve practical problems

PO4: Apply Industry 4.0 & 5.0 concepts and technologies, such as Additive Manufacturing, Internet of Things (IoT), artificial intelligence (AI), and Digital Twin in various manufacturing industries/ industrial processes and to develop sustainable manufacturing processes/systems

PO5: Able to integrate technologies such as hydraulics, pneumatics, PLC, robots, SCADA, programming, electronics, and controls to develop automated manufacturing solutions

PO6: Develop the ability to collect, analyze, and interpret data from manufacturing processes to make decisions and optimize production using AI/ML techniques

Curriculum

Bridge Course: A comprehensive bridge course has been designed to equip students with a solid foundation in several key mathematical areas and programming proficiency crucial for their academic journey and future endeavors in the domain of Manufacturing and Automation. This intensive course aims to bridge the gap between prior knowledge and the rigorous demands of the program, ensuring all students possess a solid understanding of fundamental concepts in mathematics and programming languages.

The mathematics segment of the bridge course encompasses a diverse array of topics essential for the comprehension and analysis of advanced engineering principles. Students will be familiarized with Calculus, Linear Algebra, Complex variable, Transforms, Statistics, ODE and PDE. In parallel with mathematical concepts, students will be introduced to a versatile programming language, such as Python/MATLAB, to facilitate computational analysis and problem-solving in engineering contexts. Through hands-on exercises and projects, students will gain proficiency in Basic Syntax and Data Structures, Numerical Computing, Plotting and Visualization, Algorithm Implementation and Integration with engineering applications.

(60 Hours)

First Semester

Course Code	Type	Course	L T P	Cr
24MU601	FC	Digital Manufacturing	3 0 0	3
24MU602	FC	Mechatronics System Design	3 0 3	4
24MU603	SC	AI and Machine Learning	2 0 3	3
24MU604	SC	Additive Manufacturing	2 0 0	2
24MU605	SC	Sustainable Manufacturing	3 0 0	3
24MU606	FC	Programming for Automation	1 0 3	2
24MU681	SC	Automation Lab	0 0 3	1
22AVP103	HU	Mastery Over Mind	1 0 2	2
23HU601	HU	Career Competency I*	0 0 3	P/F
		Credits		20

*** Non-credit course**

Second Semester

Course Code	Type	Course	L T P	Cr
24MU611	SC	Process Control and Automation	3 0 3	4
24MU612	SC	Robotics and Autonomous Systems	3 0 3	4
24MU613	SC	IIoT and Digital Twin	2 0 3	3
	E*	Elective I	3 0 0	3
	E*	Elective II	3 0 0	3
	E*	Elective III	3 0 0	3
23HU611	HU	Career Competency II	0 0 3	1
24RM603		Research Methodology		P/F
		Credits		21

***Can opt for NPTEL/Swayam courses with prior approval from the Department**

Third Semester

Course Code	Type	Course	L T P	Cr
24MU798		Dissertation Phase I		10
			Credits	10

Fourth Semester

Course Code	Type	Course	L T P	Cr
24MU799		Dissertation Phase II		16
			Credits	16

Total credits: 67

Electives

Course Code	Course	L T P	Cr
Stream 1: Automation Technologies			
24MU631	Virtual and Augmented Reality	2 0 3	3
24MU632	Real-Time Operating Systems	3 0 0	3
24MU633	Machine Vision Systems	3 0 0	3
24MU634	Mobile Robotics	2 0 3	3
24MU635	Cyber-Physical Systems	3 0 3	3
24MU636	Smart Sensors	3 0 0	3
24MU637	Automotive Automation	3 0 0	3
Stream 2: AI in Manufacturing			
24MU641	Explainable AI for Manufacturing	3 0 0	3
24MU642	Deep Reinforcement Learning	3 0 0	3
24MU643	Big Data Analytics for Manufacturing	3 0 0	3
24MU644	Cyber Security in Manufacturing	3 0 0	3
24MU645	Cloud Computing	3 0 0	3
Stream 3: Manufacturing and Management			
24MU651	Advanced Manufacturing Processes	3 0 0	3
24MU652	Intelligent Manufacturing Systems	3 0 0	3
24MU653	Modeling and Simulation of Manufacturing Systems	2 0 3	3
24MU654	Optimization Techniques in Engineering	2 0 3	3
24MU655	Product Life Cycle Management	3 0 0	3
24MU656	Logistics and Supply Chain Management	3 0 0	3
24MU657	Reliability Engineering	3 0 0	3
24MU658	Advances in Materials Science and Characterization	3 0 0	3
24MU659	Lean Manufacturing	3 0 0	3

EVALUATION PATTERN

<table>
<tr><th>Course Type</th><th>Int : Ext</th><th colspan="6">Evaluation Scheme</th><th colspan="2">Total (100)</th></tr>
<tr><td colspan="10">Theory, Lab integrated and Pass/Fail (P/F) Courses</td></tr>
<tr><td rowspan="2">L T P</td><td rowspan="6">60 : 40</td><td>CA1</td><td>CA2</td><td>MT</td><td>CA3</td><td>CA4</td><td>ES</td><td>Internal (60)</td><td>External (40)</td></tr>
<tr><td>Q1 /AI</td><td>Q2/ A2</td><td>Exam</td><td>Q3/ A3</td><td>Q4/ A4</td><td>Exam/ Project*</td><td>CA1+CA2+ MT+CA3+CA4</td><td>ES</td></tr>
<tr><td>X 0 0</td><td rowspan="4">7.5</td><td rowspan="4">7.5</td><td rowspan="4">30</td><td rowspan="4">7.5</td><td rowspan="4">7.5</td><td rowspan="4">40</td><td rowspan="4">60</td><td rowspan="4">40</td></tr>
<tr><td>X Y 0</td></tr>
<tr><td>X 0 Z</td></tr>
<tr><td>P/F</td></tr>
<tr><td colspan="10">Lab Based Courses</td></tr>
<tr><td rowspan="2">0 0 Z</td><td rowspan="3">60 : 40</td><td colspan="2">6 weeks Task or Exp. (CA1)</td><td rowspan="2">MT</td><td colspan="2">6 weeks Task or Exp. (CA2)</td><td>ES</td><td colspan="2">Total (100)</td></tr>
<tr><td colspan="2">No. of Task based on the course</td><td colspan="2">No. of Task based on the course</td><td>Exam/ Project*</td><td>Internal
(CA1+MT+ CA2)</td><td>External (ES)</td></tr>
<tr><td>1 0 Z</td><td colspan="2">20</td><td>20</td><td colspan="2">20</td><td>40</td><td>60</td><td>40</td></tr>
<tr><td colspan="10">Dissertation / Internship</td></tr>
<tr><td rowspan="5">DISSERTATION / INTERNSHIP</td><td rowspan="5">60 : 40</td><td colspan="5">CA (60)</td><td>ES (40)</td><td colspan="2">Total (100)</td></tr>
<tr><td colspan="8">Dissertation Phase 1 & Phase 2</td></tr>
<tr><td colspan="5">Based on Review by panel of experts</td><td>External review</td><td colspan="2">CA+ES</td></tr>
<tr><td colspan="8">Internship</td></tr>
<tr><td colspan="5">External report (Industry / Research Organization)</td><td>Presentation & Internship Report</td><td colspan="2">CA+ES</td></tr>
</table>

Nomenclature

L	: Lecture	T	: Tutorial
P	: Practical	Int	: Internal
Ext	: External	CA	: Continuous Assessment
MT	: Mid-Term	ES	: End Semester Examination
Exp.	: Experimental work	X	: No. of Lecture hours per week
Y	: No. of Tutorial hours per week (1)	Z	: No. of practical hours per week
Q	: Quiz	A	: Assignment
DIS	: Dissertation		

* : Project component (in-lieu of end semester examination) only for the selected courses as decided by the department level committee

SEMESTER 1

24MU601 DIGITAL MANUFACTURING 3-0-0-3

Course Objective

- To impart the knowledge and skills needed to leverage digital technologies effectively in a modern manufacturing environment.
- To familiarize on the emerging technologies for converting conventional manufacturing setup into a smart factory

Course Outcomes

CO	CO Description
CO1	Understand the product life cycle and apply the digital transformation tools and techniques
CO2	Develop the process plan and generate NC codes for a given component/assembly
CO3	Select appropriate technologies for converting conventional manufacturing setup into a smart factory
CO4	Identify the technology change and the future of Industry 4.0

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	1			
CO2	3	2	1			
CO3	3	1	1	3	3	2
CO4	2	1	1	3	1	1

Skills Acquired

Ability to implement digital solutions to the manufacturing environment and convert the existing factories into smart factories.

Unit 1 15 hours

Concepts and common tools for digital manufacturing - product design and development life cycle, product design process, design for function, reliability, production, and cost. Conceptual design and CAD, CAE in manufacturing, process planning, CAPP, CNC machines, CNC programming, drivers for digital transformation, production process simulation, PLM systems, and CAE.

Unit 2 15 hours

Emerging technologies in industry- direct digital manufacturing- additive manufacturing technologies for on-demand production - 3D printing - laser engineered shaping - reverse engineering. Self-configuration and self-diagnosis methods based on Internet of Things technologies, machine learning and AI for manufacturing processes, reconfigurable manufacturing systems, monitoring and intelligent control of production and logistics/supply chain - smart energy management - virtual, augmented reality and collaborative robots for design, production, and logistics.

Unit 3 15 hours

Industry 4.0 components, characteristics, and design principles, building blocks, digitalization, and the networked economy, drivers, enablers, comparison of industry 4.0 factory and today's factory, trends of industrial big data and predictive analytics for smart business transformation, digital transformation challenges.
Interoperability, Communication systems and standards for Industry 4.0, virtualization, Decentralization, Modularity, real-time capability, information transparency. Industry 5.0 – Potential Opportunities and Adaptation challenges-cyber physical cognitive systems, mass customization, and human-machine interface.

Text Books / References

1. Zude Zhou, Shane (Shengquan) Xie , Dejun Chen, " Fundamentals of Digital Manufacturing Science", Springer, 2012.
2. R. K. Amit, Kulwant S. Pawar, R. P. Sundarraj, Svetan Ratchev, "*Advances in Digital Manufacturing systems*", Springer 2023.
3. Divya Zindani , J. Paulo Davim , Kaushik Kumar, "*Digital Manufacturing and Assembly Systems in Industry 4.0*", CRC Press, 2021.
4. Santosh Rane, Bhaveshkumar N. Pasi ,Subhash K. Mahajan, "*Development of Smart Manufacturing System: An Industry 4.0 Perspective*", Book Rivers, 2024.
5. Alp Ustundag, Emre Cevikcan, "*Industry 4.0: Managing the Digital Transformation*" Springer, 2018.

24MU602 MECHATRONICS SYSTEM DESIGN 3-0-3-4

Course Objective

- To familiarize about the integration of electronics in mechanical design for automation applications
- To understand the use of different types of microprocessors/microcontrollers on mechatronics system design

Course Outcomes

CO	CO Description
CO1	Understand the basics of the mechatronics-based design approach and the components involved
CO2	Develop mathematical models for rotational translational, electromechanical, and hydraulic-mechanical systems and understand the input/output characteristics of different types of control systems
CO3	Describe the detailed architecture, internal modules, and addressing modes of ARM-based processors and interfacing with sensors & actuators
CO4	Develop assembly and high-level language programs for various automation applications

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	1	1	1	
CO2	3	1	1	1	1	
CO3	3	1	2	1	3	
CO4	2	2	3	1	3	

Skills Acquired

Ability to implement digital solutions to the manufacturing environment and deploy mechatronics principles.

Unit 1 12 hours

Introduction to Mechatronics, application areas of mechatronics, design process, systems, measurement and control system, review of sensors and transducers, signal conditioning- operational amplifier, filtering, pulse modulation, analog and digital signals, actuation systems- mechanical, pneumatic, hydraulic, and electrical actuation.

Unit 2 15 hours

System models- mathematical models, building blocks-mechanical, electrical, fluid systems, thermal systems, electromechanical, modeling dynamic systems: first order and second order, performance measures, transfer functions, systems with feedback loops, systems in series, closed-loop controllers, proportional, integral, derivative, PID, adaptive and digital control systems, Mechatronic designs -case studies.

Unit 3 18 hours

Microprocessor building blocks, combinational and sequential logic elements, memory, timing, and instruction execution fundamentals with an example of primitive microprocessor, Introduction to Embedded Processors. ARM Architecture – Programmer's Model, Pipelined data path design. Memory system design- Cache Memory, Memory Management unit, Virtual Memory. Overview of 8-bit and 16-bit microcontrollers. Introduction to ARM-based Microcontrollers – Architecture, Peripherals - Input/output ports, Timers, ADC, DAC, PWM, Quadrature Encoder, Advanced communication interfaces.

Lab Exercises 12 Sessions

Familiarization with IDE, simulator, development boards, and kits, Embedded C Program to configure and use Input/output ports & Timers, ADC and DAC, PWM, UART, SPI, I^2C, Interfacing of sensors and actuators to microcontroller, Development of robotic and automation applications.

Text Books / References

1. William Bolton, "*Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering*", 7th Edition, Pearson, 2019.
2. Devdas Shetty, Richard A. Kolk, "*Mechatronics System Design," 2nd Edition*(SI), Cengage Learning, 2011.
3. Saurabh Chandrakar Nilesh Bhaskarrao Bahadure, "*Microcontrollers and Embedded System Design*", First Edition, Dreamtech Press, 2019.
4. William Hohl and Christopher Hinds, "*ARM Assembly Language: Fundamentals and Techniques*", Second Edition, CRC Press, 2016.
5. Curtis D. Johnson, *Process Control Instrumentation Technology*, Eighth Edition, Pearson, 2014

24MU603 **AI AND MACHINE LEARNING** **2-0-3-3**

Course Objectives

- Provide a strong foundation of fundamental concepts in Artificial Intelligence
- Elobarate different AI and machine learning techniques for design of AI systems.

Course Outcomes

CO	CO Description
CO1	Understand the basics of probability and statistical learning for artificial intelligence
CO2	Apply AI and ML techniques which involve perception, reasoning and learning
CO3	Analyze a real world problems and solve it using machine learning and deep learning techniques
CO4	Develop ML models using advanced techniques for various automation applications

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	1	1	1	3
CO2	3	1	1	1	1	3
CO3	3	1	2	1	1	3
CO4	3	1	3	2	1	3

Skills Acquired

Formulate engineering problems as a machine learning problem; Select appropriate solution methods and strategies to solve machine learning problems; Solve engineering design-related machine learning problems using software tools.

Unit 1 **10 hours**

Basic motivation, examples of machine learning applications, Supervised and Unsupervised Learning – Review linear algebra, vector spaces, linear transformations, eigenvalues, and vectors – Review of statistics and probability theory, random variables, and probability distributions. Basic concepts of fuzzy sets – Operations on fuzzy sets –Fuzzy relation equations – Fuzzy logic control – Fuzzification – Defuzzification – Knowledge base – Decision making logic – Membership functions – Rule base.

Unit 2 **10 hours**

Multiple Variable Linear regression, Multiple regression, Logistic regression, K-NN classification, Naive Bayes classifiers, and Support vector machines.

K-means clustering, Hierarchical clustering, High-dimensional clustering, Dimension ReductionPCA, Ensemble techniques Decision Trees, Random Forests, Bagging, Boosting-Value based methods Q-learning.

Reinforced learning.

Unit 3 **10 hours**

Introduction – history of neural networks – multilayer perceptrons –Back propagation algorithm and its variants – Different types of learning, examples, Deep learning - Convolutional Neural Networks (CNNs), Long Short-Term Memory (LSTM). Generative Adversarial Networks (GANs). Model Evaluation and Validation - Cross-validation techniques, Evaluation metrics for regression and classification tasks, Bias-variance tradeoff, Feature Engineering, and Model Optimization.

Lab Practice **12 Sessions**

- Pattern recognition-based online monitoring system for machinery fault diagnosis using support vector machine.
- Decision tree assisted selection of materials for electric vehicle chassis.
- Predicting the optimal input parameters for the desired print quality using an artificial neural network.
- Exploration of the K-NN algorithm to predict fatigue strength of steel from composition and processing parameters.
- Prediction of remaining useful life of machine component using Support Vector Regression and LSTM
- Generation of 3D CAD model for mechanical parts using Generative Adversarial Networks (GAN)
- A deep learning approach for detection of obstacles for autonomous driving systems using CNN.
- A multi-sensor information fusion for fault diagnosis of a mechanical system utilizing discrete wavelet features.
- Physics-informed machine learning-based fault diagnosis of machine elements.
- Prediction of weld quality using image processing techniques.

Text Books / References

1. Chandra S.S.V *Artificial Intelligence and Machine Learning,* Prentice Hall India Learning Private Limited; 4th edition, 2018.
2. Tom M. Mitchell, "*Machine Learning*", McGraw Hill, 1997.
3. Ethem Alpaydin, "*Introduction to Machine Learning*", MIT Press, 2015.
4. C. M. Bishop, "*Pattern Recognition and Machine Learning*", Springer, 2006.
5. C. Muller and S. Guido, "*Introduction to Machine Learning with Python*", O'Reilly Media, 2017.
6. Goodfellow, YoshuaBengio and Aeron Courville," *Deep Learning*", MIT Press, First Edition, 2016.
7. 6Guttag, John., "*Introduction to Computation and Programming Using Python: With Application to Understanding Data*", Second Edition. MIT Press, 2016.

24MU604 **ADDITIVE MANUFACTURING** **2-0-0-2**

Course Objectives

- To make students understand the wide range of additive manufacturing processes, capabilities, and materials
- To provide comprehensive knowledge of the various software tools and techniques that enable additive manufacturing.
- To make the students learn to create physical objects that satisfy product development/prototyping requirements, using /additive manufacturing processes.

Course Outcomes

CO	CO Description
CO1	Understanding the principles of various additive manufacturing processes
CO2	Demonstrate competency in the behaviour of materials used for additive manufacturing processes
CO3	Interface CAD tools effectively with additive manufacturing systems
CO4	Identify suitable additive manufacturing processes, define optimum process parameters, and develop physical prototypes using suitable additive manufacturing systems

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2		2	3	1	
CO2	2		2	3	1	
CO3	2		2	3	1	
CO4	2		2	3	1	

Skills Acquired

Selection of suitable additive manufacturing technique for a given application, finishing of additive manufactured part, CAD data transfer to additive manufacturing, technology for metal additive manufacturing

Unit 1 **10 Hours**

Introduction: Methods and Systems: Introduction to layered manufacturing, Importance of Additive Manufacturing, Additive Manufacturing in Product Development. Classification of additive manufacturing processes, Common additive manufacturing technologies; Fused Deposition Modeling (FDM), Selective Laser Sintering (SLS), Stereo Lithography (SLA), Selection Laser Melting (SLM), Digital Laser Processing (DLP), Jetting, 3D Printing, Laser Engineering Net Shaping (LENS), Laminated Object Manufacturing (LOM), Electron Beam Melting (EBM), Wire Arc Additive Manufacturing (WAAM), Electro Chemical AM, 4D Printing. Capabilities, materials, costs, advantages, and limitations of different systems.

Unit 2 **10 Hours**

Material and Process Evaluation: Material science for additive manufacturing - Mechanisms of material consolidation. FDM, SLS, SLM, 3D printing, and jetting technologies. Polymers coalescence and sintering, photopolymerization, solidification rates, Meso and macro structures, Additive Manufacturing of composite materials. Process evaluation: process-structure relationships, structure-property relationships, Post-processing: Heat treatment, shot peening, HIPS, Micro finishing of AM parts, Applications: Prototyping, Industrial tooling, Aerospace, Automobile, Medical etc., Quality control and reliability: Defects in FDM, SLS and SLM, Critical process parameters: geometry, temperature, composition, phase transformation, Numerical and experimental evaluation: roles of process parameter combination, process optimization.

Unit 3 **10 Hours**

CAD in Additive Manufacturing: CAD Modelling for 3D printing: 3D Scanning and digitization, data handling &reduction Methods, AM Software: data formats and standardization, Slicing algorithms: uniform flat layer slicing, adaptive slicing, Process-path generation: Process-path algorithms, rasterization, part Orientation and support generation. Design for Additive Manufacturing: Design for minimum material usage, Topology design optimization, Mass customization, Generative Design, Part consolidation, Design guidelines for extrusion, liquid and powder-based AM.

Text Books / References

1. Gibson, I., Rosen, D.W. and Stucker, B., *"Additive Manufacturing Methodologies: Rapid Prototyping to Direct Digital Manufacturing",* Springer, 2010.
2. Chua, C.K., Leong K.F. and Lim C.S., *"Rapid prototyping: Principles and applications"*, second edition, World Scientific Publishers, 2010.
3. Liou, L.W. and Liou, F.W., *"Rapid Prototyping and Engineering applications : A tool box for prototype development",* CRC Press, 2011.
4. Kamrani, A.K. and Nasr, E.A., *"Rapid Prototyping: Theory and practice",* Springer, 2006.
5. Hilton, P.D. and Jacobs, P.F., "*Rapid Tooling: Technologies and Industrial Applications"*, CRC press, 2005.

24MU605 **SUSTAINABLE MANUFACTURING** **3-0-0–3**

Course Objectives

- To provide a practical level understanding of key factors in sustainable manufacturing
- To impart knowledge on sustainable models and frameworks
- To inculcate the practice of sustainability in manufacturing

Course Outcomes

CO	CO Description
CO1	Identify key requirements in sustainable manufacturing
CO2	Apply sustainability concepts in manufacturing systems
CO3	Demonstrate the life cycle analysis and costing in the production process
CO4	Map the possibilities in remanufacturing and circular economy in manufacturing

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1	2	3		
CO2	2	1	2	3		
CO3	2	1	2	3		
CO4	2	1	2	3		

Skills Acquired

Assess the sustainability of a manufacturing industry, and develop sustainable and green manufacturing processes and products.

Unit 1 **10 hours**

Concept of sustainability, Sustainable Development goals, manufacturing operations, resources in manufacturing. Concept of the triple bottom line, environmental, economic, and social dimensions of sustainability. Need for sustainable manufacturing. Environmental impact assessment methods - CML, EI 95 and 99, ISO 14001, EMS and PAS 2050 standards, environmental impact parameters. Sustainability assessment-concept models and various approaches, product sustainability and risk assessment-corporate social responsibility.

Unit 2 **10 hours**

Life cycle analysis tools, optimization for achieving sustainability in manufacturing, value analysis, analysis for carbon footprint-software packages for sustainability analysis, Life Cycle Cost Analysis. Remanufacture and disposal - Environmental conscious- quality function deployment- R3 and R6 cycles – Remanufacturing case studies, EoL Waste valorization techniques, Industrial symbiosis, Circular economy strategies. Environmental Impacts of Manufacturing, Cutting Tool Sustainability, Minimum Quantity Lubrication in Machining.

Unit 3 **10 hours**

Environmentally conscious quality function deployment (ECQFD), Life Cycle Design, Facilitating Disassembly, System Design for Eco-efficiency, Environmental Complexity and Designing Activity, and Product Lifetime Optimisation. Sustainable smart manufacturing in Industry 4.0-recent developments in metal joining techniques, machining, Green and Sustainable Manufacturing Processes for Motor Cores in EV- Industrial case studies on sustainable smart manufacturing.

Text Books / References

1. S.Vinodh, "*Sustainable Manufacturing Concepts, Tools, Methods and Case Studies*", CRC Press, 2020
2. Kapil Gupta, "*Sustainable Manufacturing*", Elsevier Science Publishing Co Inc, Springer, 2021
3. Dornfeld, David, *Green Manufacturing*, Springer-Verlag, New York, 2012
4. Rainer Stark, Günther Seliger, Jérémy Bonvoisin, " *Sustainable Manufacturing: Challenges, solutions and implementation perspectives*, Springer, 2017.
5. Gupta, S.M. and Lambert, A.J.D., "*Environment Conscious Manufacturing*", CRC Press, 2008.

24MU606 PROGRAMMING FOR AUTOMATION 1-0-3-2

Course Objectives

- Enable Python programming skills for scientific computing.
- Provide hands-on programming for practical prediction-based applications.
- Expose the development of graphical user interface design using Virtual Instrumentation tools.

Course Outcomes

CO1	Develop simple programs with scripts and control statements
CO2	Apply data analytics using Python scientific packages
CO3	Design a graphical system using Virtual Instrumentation software

CO- PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1	2			1
CO2	2	1	2		2	2
CO3	2	1	2		2	2

Skills Acquired

Problem-solving of the physical systems/mathematical models using Python programming, development of graphical user interface using VI software.

Unit 1 7 Sessions

Python Programming: Introduction to Python: motivation for learning Python in various engineering applications. data types: variables, assignments; immutable variables; numerical types; arithmetic operators and expressions; Boolean logic, logical operators: ranges; control statements; Reading/writing text and numbers from/to a file; creating and reading a formatted file. Lists, tuples, set, and dictionaries: basic list operators, replacing, inserting, removing an element; searching and sorting lists; adding and removing keys, accessing, and replacing values; traversing dictionaries. Python packages for scientific computing: Numpy, SciPy, Pandas, Scikit-learn. Data analysis with Python.

Unit 2 5 Sessions

Graphical User Interface Design: Traditional and virtual instruments. Data types, G-Programming, Concept of VIs and sub-VIs, Graphs and charts, Local and Global variables – String and file I/O, Control loops and structures, sequence structures, and Data acquisition system. Signal processing and analysis, Graphical system design.

Text Books / References

1. Guttag, John., "*Introduction to Computation and Programming Using Python: With Application to Understanding Data*", Second Edition. MIT Press, 2016. ISBN:9780262529624.
2. William McKinney, "*Python for Data Analysis: Data Wrangling with Pandas, NumPy, and Ipython*", Second edition (27 October 2017), Shroff/O'Reilly, ISBN-10: 9789352136414, ISBN-13: 978-9352136414.
3. Hans Fangohr, "*Introduction to Python for Computational Science and Engineering (A beginner's guide)*", Faculty of Engineering and the Environment University of Southampton,September 7, 2015.
4. Gupta, Virtual Instrumentation Using LabVIEW 2E, Tata McGraw-Hill Education, 2010.

24MUU681 **AUTOMATION LAB** **0-0-3-1**

Course Objectives

- To acquaint students with the concept of Additive Manufacturing (AM), various AM technologies, selection of materials for AM, modeling of AM processes, and their applications in various fields.
- To provide hands-on experience in automation with hydraulics, pneumatics, and CNC
- To give exposure to the fabrication of metal welded joints using various materials by GTA / GMA welding processes.

Course Outcomes

CO	CO Description
CO1	Understanding the concepts, capabilities, and limitations of additive technologies and their varied applications.
CO2	Familiarize on the operation and programming of CNC machines
CO3	Design of hydraulic and pneumatic circuits for various automation applications
CO4	Fabricate a welded joint of different materials using the GTA and GMA process and analyze the microstructure of the welded joint by varying the process parameters.

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	1	2	2	
CO2	2	2	1	2	2	
CO3	2	2	1	2	3	
CO4	2	2	1	1	2	

Skills Acquired

3D printing, CNC programming, advanced welding techniques.

Syllabus **12 Sessions**

3D Printing: CAD Modelling: Introduction to CAD environment, Sketching, Modelling, and Editing features, Different file formats, Export/Import geometries, Part orientation, Slicing, Support generation-FDM/SLA, Process path selection, Printing-FDM/SLA.

CNC: CNC Programming, CNC machining center, lathe, CAM – Machining Simulation and CNC code generation, high-speed machining. Automation: Design and simulation of pneumatic, electro-pneumatic, hydraulic, and electro-hydraulic circuits for industrial automation applications.

Analyze the effect of weld quality due to GTAW/GMAW process parameters such as welding current, travel speed, and stand-off distance. Measurement of weld bead geometry elements using macrostructure analysis.

SEMESTER 2

24MU611 PROCESS CONTROL AND AUTOMATION 3-0-3-4

Course Objectives

- To provide the student with the fundamentals of PLC, SCADA, and DCS
- To facilitate the design of automated systems using software tools.

Course Outcomes

CO	CO Description
CO1	Develop the PLC program for the given application
CO2	Interface the Input and output devices with PLC
CO3	Understand the concepts of SCADA and its applications
CO4	Implement suitable communication and networking technology for industrial applications

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1	2	1	3	
CO2	3	1	2	1	3	
CO3	3	1	2	1	3	
CO4	3	1	2	1	3	

Skills Acquired

PLC programming, SCADA, automation using DCS, development of HMI

Unit 1 15 Hours

Automation in the manufacturing system, Principles, and strategies of automation, Basic elements of an automated system, Advanced automation functions, Levels of automation, Automated flow lines and transfer mechanisms, Programmable Logic Controllers: Introduction, Types of PLC, CPU unit architecture, Memory classification, Input/output devices and their interfacing, Digital-Analog modules, Communication modules, Special function modules, Basic Ladder logic, electrical wiring diagram, scan cycle. Programming languages for PLC, PLC module addressing, registers basics, basic relay instructions, timer-counter instructions, Math functions, data handling, and program control instructions.

Unit 2 15 Hours

SCADA: Introduction to computer-based industrial automation- Direct Digital Control (DDC), Distributed Control System (DCS), and Supervisory Control And Data Acquisition (SCADA) based architectures and HMI Components, HMI Development, Data Processing, Control Algorithm, Programming, Data Acquisition from PLCs/RTUs, Database Connectivity and Report generation. OPC Configuration with RTUs (PLC), Cyber Security for Industrial Control Systems.

Unit 3 15 Hours

Distributed Control System- Local Control Unit (LCU) architecture, LCU Process Interfacing Issues, Block diagram and Overview of different LCU, security design approaches, Networking of DCS. Introduction to communication protocols Profibus, Field bus, HART protocols. Data gathering, Data analytics, Real-time analysis of data stream from DCS, Historian build, Integration of business inputs with process data.

Levels of process safety through the use of PLCs, Integrating Process safety PLC and DCS, Application of international standards in process safety control.

Lab Exercises **12 Sessions**

Ladder programming for boolean operations & math operations, Development of combinational and sequential logic applications using PLC languages, Interfacing of Electro-Pneumatic system with PLC, Speed control of DC motor using PLC, Interfacing HMI with PLC.

Interfacing PLC real-time TAG with SCADA, Flow and pressure measurement and control using SCADA, and Development of SCADA for control of processes. Study of HART and Field bus protocol P&I diagram development using simulation software for complex processes. Study of Distributed Control System and different instruction sets.

Text Books / References

1. B. R. Mehta and Y. J. Reddy, *Industrial Process Automation Systems Design and Implementation,* Elsevier Inc. 2015.
2. Lukas M.P, "*Distributed Control Systems*," Van Nostrand Reinhold Co., New York, 1986.
3. K.L.Sharma, *Overview of Industrial Process Automation*, Elsevier, 2011
4. Petruzella, Frank D. *Programmable logic controllers*. Tata McGraw-Hill Education, 2005.
5. Frank Lamb, *Industrial Automation: Hands On*, McGraw-Hill Professional, 2013

24MU612 ROBOTICS AND AUTONOMOUS SYSTEMS 3-0-3-4

Course Objectives

- Introduce the modeling, simulation, and control of spatial multi-degree-of-freedom robotic manipulators.
- Familiarize on the kinematics and dynamics of robotic manipulators.
- To give exposure to autonomous systems, controls, and applications

Course Outcomes

CO	CO Description
CO1	Design appropriate end effectors for various applications.
CO2	Analyze the kinematics of various manipulator configurations
CO3	Compute required trajectory planning for the given task
CO4	Develop appropriate control for autonomous applications

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1	2	1	3	
CO2	3	1	2	1	3	
CO3	3	1	2	1	3	
CO4	3	1	2	1	3	

Skills Acquired

Selection of robots, robot programming, trajectory planning, development of autonomous systems

Unit 1 10 Hours

Introduction: Definition, Classification, Robot Components, Degree of Freedom, Mobile Robots, Robot Characteristics, Robot Workspace, Robot specifications, and programming. Application of Robots. End Effectors-Grippers-Types: Pneumatic, Hydraulic, Magnetic, Vacuum Grippers, Spherical Wrist; Selection and Design Considerations, resolution, accuracy, and repeatability of robot, applications.

Unit 2 15 Hours

Manipulator Dynamics: Lagrangian Mechanics, Dynamical models of multiple DOF robots, robot workspace analysis, Static force analysis of robots, Transformation of forces and moments between coordinate frames. Dynamic algorithms and Introduction to recursive robot dynamics. Trajectory Planning: Robot workspace analysis, joint space trajectories, path and trajectory planning of a robot, Trajectory Interpolation, Setpoint tracking, and Actuator Dynamics. Cartesian-Space Trajectories, Continuous trajectory recording.

Unit 3 15 Hours

Introduction to the concept of Autonomous Systems (AS). Introduction to high-level mission planning and execution of AS. AS for autonomous intelligent inspection. Introduction to safe, reliable, and verifiable AS. Software and Hardware architectures for AS. Introduction to the physical interaction of AS. Perception for AS - Multiple View Geometry, Image Feature Detection and Description, Ranging, 3D Cloud Processing, Object Pose Estimation, State Estimation, Classification, Visual Odometry, SLAM, and Object Detection. Introduction to robust control of AS. Introduction to Machine Learning in AS. Study the current technology and use of intelligent industrial controllers utilized in electric energy, manufacturing, material handling/processing, mass transit, and other industrial plants. Selection and programming of Programmable Automation Controllers (PACs), Programmable Logic Controllers (PLCs), and Distributed Control Systems (DACs).

Lab Exercises **12 Sessions**

Dynamic modeling of an industrial robot manipulator, Inverse and forward dynamics of robot manipulator, Trajectory Planning of 3R robot based on 3rd order polynomial trajectory, Computation of geometric Jacobian for robot manipulator, Trajectory tracking control of industrial robotic arm using robot manipulator blocks, Rotational and transform trajectory analysis of robot manipulator, Design and develop the manufacturing cell using virtual robot simulator. Develop a TCP and work object for an Industrial Robot using a Robot simulator. Develop the robot programming for pick and place of objects, material handling, and welding operations. Part identification based on color & pattern and separate the components using vision system and Robot.

Text Books / References

1. Hexmoor, Henry, *Essential Principles for Autonomous Robotics*, Springer, 2013.
2. Yue Yufeng, Wang Danwei, *Collaborative perception, localization and mapping for autonomous systems*, Springer, 2021.
3. Cameron Hughes, Tracey Hughes, *Robot Programming: a Guide to Controlling Autonomous Robots*, Que Publishing, 2016
4. Mikell P. Groover, *Automation, Production Systems, and Computer-Integrated Manufacturing*, Pearson Education, 2016.

24MU613 **IoT AND DIGITAL TWIN** **2-0-3-3**

Course Objectives

- To impart the basic knowledge on the drivers, enablers, and design principles of Industry 4.0.
- To introduce digital twins concepts and their applications in the industry

Course Outcomes

CO	CO Description
CO1	Enumerate different communication technologies used in Industry 4.0.
CO2	Perform edge, and cloud computing and visualize the data
CO3	Introduce the concept of Digital Twins in manufacturing the industry
CO4	Design Digital Twins for discrete and process industries

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	2	3		
CO2	3	1	2	3		
CO3	3	1	2	3		1
CO4	3	1	2	3	1	1

Skills Acquired

Industry 4.0, IIOT implementation, development of digital twin for a given application.

Unit 1 **10 Hours**

Introduction: The various industrial revolutions, digitalization, and the networked economy, drivers, enablers, comparison of industry 4.0 factory and today's factory, challenges. Communication Technologies of IIoT Communication Protocols: IEEE 802.15.4, ZigBee, Z Wave, Bluetooth, BLE, NFC, RFID, Industry standards communication technology (LoRA, WAN, OPC UA, MQTT), connecting into existing Modbus and Profibus technology, wireless network.

Unit 2 **10 Hours**

Visualization and Data Types of IIoT Communication. Front-end EDGE devices, Emerging descriptive data standards for IIoT, Cloud database, Could computing, Fog/Edge computing. Pushing data to the cloud. Grabbing the content from a web page, Sending data on the web, Troubleshooting. Application of IIOT Case study: Health monitoring, smart city, Smart irrigation, Robot surveillance.

Unit 3 **10 Hours**

Design of Digital Twins: Technological needs. Physics-based approach: Model identification, Model creation. Data-driven approach: Model development using ML/DL models. Digital twins for Prototype, Product, and Performance. Digital Twins validation. Control system requirements in a Discrete Industry, Digital Twins of a Product, Digital Thread in a Discrete Industry, Data Collection & Analysis for Product & production improvements, Automation Simulation, and Digital Enterprise. Process Industry: Basics of Process Industry, Trends in the process industry, control system requirements in a process industry, Digital Twins of a plant, Digital Thread in Process Industry.

Lab Experiments **12 Sessions**

Modules and Sensors Interfacing (LM35, DHT 11, POT, IR sensor, Ultrasonic sensors) using Raspberry Pi/Node MCU, Modules and Actuators Interfacing (Relay, Motor, Buzzer) using Raspberry Pi/Node MCU

Demonstration of MQTT, LoRa communication, Visualization of diverse sensor data using dashboard (part of IoT's 'control panel'), Device control using mobile Apps or through Web pages, Machine to Machine communication, Fault Diagnosis of rotating elements using Digital Twins, Digital Twins modeling of the Drilling system, Validation and performance optimization of the Digital Twins model of the Drilling system, Digital Twins for fan speed control system, Develop Predictive Models using Digital Twins.

Text Books / References

1. Bruno S.Sergi, Elena G.Popkova, Aleksei V. Bogoviz and Tatiana N. Litvinova, "*Understanding Industry 4.0: AI*, *The internet of things, and the future of work*", Emerald publishing limited, 2019.
2. Alp Ustundag and Emre Cevikcan, "*Industry 4.0: Managing the Digital Transformation*", Springer Series in Advanced Manufacturing., Switzerland, 2017.
3. Andrew Yeh Chris Nee, Fei Tao, and Meng Zhang, "*Digital Twin Driven Smart Manufacturing*", Elsevier Science., United States, 2019.
4. Shyam Varan Nath, Pieter van Schalkwyk, Dan Isaacs, "*Building Industrial Digital Twins Design, Develop, and Deploy Digital Twin Solutions for Real-world Industries Using Azure Digital Twins*", Packt Publishing, 2021.

24RM603 **RESEARCH METHODOLOGY** **P/F**

Course Objectives

- To develop an understanding of the basic framework of research process
- To identify various sources of information for literature review and data collection
- To develop an understanding of the ethical dimensions of conducting applied research

Course Outcomes

CO	CO Description
CO1	Understand research problem formulation
CO2	Analyse research related information
CO3	Follow research ethics
CO4	Understand that today's world is controlled by Computer, Information Technology, but tomorrow world will be ruled by ideas, concept, and creativity.
CO5	Understanding that when IPR would take such important place in growth of individuals & nation, it is needless to emphasis the need of information about Intellectual Property Right to be promoted among students in general & engineering in particular
CO6	Understand that IPR protection provides an incentive to inventors for further research work and investment in R & D, which leads to creation of new and better products, and in turn brings about, economic growth and social benefits

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	1	2			
CO2	1	1	3			
CO3	1	1	2			
CO4	1		3			
CO5	1	1	2			
CO6	1	1	2			

Skills Acquired:

Research problem identification, solution strategies, research ethics, report writing, IPR

Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations

Effective literature studies approaches, analysis Plagiarism, Research ethics.

Effective technical writing, how to write report, Paper, Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee

Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT.

Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications.

New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs.

Text Books / References

1. Stuart Melville and Wayne Goddard, “*Research methodology: an introduction for science & engineering students*”, Juta & Co. Ltd., 1996.
2. Wayne Goddard and Stuart Melville, “*Research Methodology: An Introduction*”, Juta & Co. Ltd., 2004.
3. Ranjit Kumar, 3rdEdition, “*Research Methodology: A Step-by-Step Guide for beginners*”,SAGE Publications, 2010.
4. Halbert, “*Resisting Intellectual Property*”, Taylor & Francis Ltd ,2007.
5. Mayall, “*Industrial Design*”, McGraw Hill, 1992.
6. Niebel, “*Product Design*”, McGraw Hill, 1974.
7. Asimov, “*Introduction to Design*”, Prentice Hall, 1962.
8. Robert P. Merges, Peter S. Menell, Mark A. Lemley, “*Intellectual Property in New Technological Age*”, 2016.
9. T. Ramappa, “*Intellectual Property Rights Under WTO*”, S. Chand, 2008

ELECTIVES
STREAM 1: AUTOMATION AND AUGMENTED REALITY

24MU631 VIRTUAL AND AUGMENTED REALITY 2-0-3-3

Course Objectives

- Provide an overview of the opportunities in the development of VR/AR applications with a multimodal perspective and approach.
- Demonstrate the principles and multidisciplinary features of virtual reality.
- Demonstrate the VR/AR system framework and development tools.

Course Outcomes

CO	CO Description
CO1	Identify, examine, and develop software that reflects fundamental techniques for the design and deployment of AR/VR experiences.
CO2	Choose, develop, explain, and defend the use of designs for VR experiences.
CO3	List and comprehend the suitable components and devices required for AR.
CO4	Conduct an inter disciplinary research in health care and manufacturing system through AR and VR.

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	1	2		
CO2	3	1	1	3		
CO3	3	1	1	2		
CO4	3	1	1	3		

Skills Acquired

Selection of AR/VR tools for the given application and its Implementation for automation applications.

Unit 1 15 Hours

Introduction to virtual and augmented reality, features of VR, mental aspects of VR experience, reality-virtuality continuum, features of AR compared to VR, subsystems of AR and VR, visual perception, stereo vision, perpetual aspects of VR- Depth perception, motion perception and colour perception, preparation of 3D models for VR/AR -3D rotation inverses and conversions, homogeneous transforms, transforms to displays, look-at and eye transforms, canonical view and viewport transforms, optimization techniques for 3D objects, light, sound and background. Graphical rendering, ray tracing, shading, BRDFs, rasterization, barycentric coordinates, VR rendering problems, anti-aliasing, distortion shading, image warping (time warp), panoramic rendering.

Unit 2 15 Hours

VR/AR Input devices and tracking, tracking techniques – marker based, camera based tracking - Intrinsic and Extrinsic Camera Parameters, feature based tracking methods, finger and eye tracking -methods- image processing for eye tracking,calibration, head-mounted displays , mechanical input devices. VR/AR output devices- head mounted displays -open and closed - characteristics and properties of HMDs, VR and AR glasses, stationary VR systems,stereo output methods. Audio and haptic output devices.

Unit 3 15 Hours

Interaction with virtual world, interaction design, navigation, control techniques, human centered design for AR/VR interaction, real time aspects of AR systems -collision detection.

Case Studies: Traditional and emerging VR/AR applications in manufacturing- decision support system for integrating real-time manufacturing control with a virtual environment, virtual assembly/disassembly system using natural human interaction and control, the intelligent welding gun: augmented reality for experimental vehicle construction. Training Implementation. Touch, haptics and robotic interfaces, telepresence and Brain-machine interfaces.

Text Books / References

1. Ralf Doerner, Wolfgang Broll, Paul Grimm, Bernhard Jung, "*Virtual and Augmented Reality (VR/AR) Foundations and Methods of Extended Realities (XR)*", Springer, 2022.
2. Steven M. LaValle, *Virtual Reality*, Cambridge University Press, 2016.
3. William R Sherman and Alan B Craig, "*Understanding Virtual Reality: Interface, Application and Design, , (The Morgan Kaufmann Series in Computer Graphics)*". Morgan Kaufmann Publishers, San Francisco, CA, 2002 .
4. S.K. Ong and A.Y.C. Nee, "*Virtual and Augumented Reality applications in manufacturing*", Springer, 2004.

24MU632 REAL TIME OPERATING SYSTEMS 3-0-0-3

Course Objectives

- To make students' understand the Real-Time Operating System (RTOS).
- To make students' learn various approaches to real-time scheduling and other kernel services.
- To familiarize on Robot Operating System (ROS).

Course Outcomes

CO	CO Description
CO1	Identify the basic concepts in real time systems
CO2	Describe various services provided by the RTOS Kernel.
CO3	Analyse various algorithms of RTOS kernel services
CO4	Develop real time applications using ROS framework

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	2	2		
CO2	3	3	2	2		
CO3	3	3	2	2		1
CO4	3	3	2	2	1	1

Skills Acquired

Implement scheduling in real-time, develop ROS based applications for automation.

Unit 1 15 Hours

Overview of concepts of Operating System, GPOS functionalities, Architecture of OS (Monolithic, Microkernel, Layered, Exokernel and Hybrid kernel structures). Evolution of operating systems. Introduction to real-time systems, RTOS basic architecture, RTOS vs GPOS. POSIX Standards. RTOS Kernel, Kernel services.

Unit 2 15 Hours

Task Management - tasks, process and threads, task attributes and types - task states and transition, preemption-context switching, task control block, Introduction to real-time task scheduling, clock-driven and priority-driven scheduling, uniprocessor scheduling and multiprocessor scheduling concepts. Blocking, Deadlock and avoidance strategies, priority inversion and solutions. Task Communication and Synchronization - Semaphores and Mutex, Mailbox, Queue, Pipes. Timer Management, Interrupt handling, Memory Management – Cache and Virtual Memory, Input-Output handling.

Unit 3 15 Hours

Familiarization of ROS – architecture, sensors and actuators supported, computing platforms. Experiment on Creating, building, modifying packages and Writing, building source code and nodes, Creating and Running Publisher, Subscriber Nodes, Service Servers, Client Nodes, Action Server and Client Node. Programming experiment on nodes with setting, reading, building, running, displaying parameters list. Programming with ROS. Experiments - ROS launch, 3D visualization tool (RViz), Design and development of graphical user interface in ROS environment. Establish communication between robot client and server, and analysis of data packet loss Visualization of robot and their movements in Rviz ROS.

Text Books / References

1. Qing Li, Caroline Yao, “*Real-Time Concepts for Embedded Systems*” First Edition, CRC Press, 2010.
2. Douglas Wilhelm Harder, Jeff Zarnett, Vajih Montaghami and Allyson Giannikouris, “*A practical introduction to real-time systems for undergraduate engineering*”, First Edition, University of Waterloo, 2015.
3. Tanenbaum, "*Modern Operating Systems*,” Fourth Edition, Pearson Edition, 2014.
4. Jane W.S. Liu, “*Real -Time Systems*”, First Edition, Pearson Education, 2000.
5. Lentin Joseph, “*Robot Operating System (ROS) for Absolute Beginners: Robotics Programming Made Easy*”, First Edition, Apress, 2018.
6. Kumar Bipin, “*Robot Operating System Cookbook*”, First Edition, Packt Publishing, 2018.

24MU633 MACHINE VISION SYSTEMS 3-0-0-3

Course Objectives

- Introduce students to the fundamentals of image formation and review image processing techniques
- To make students' understand the shape and region analysis.
- Develop an appreciation for various issues in the design of computer vision and object recognition systems

Course Outcomes

CO	CO Description
CO1	Demonstrate the image processing and image analysis techniques by a machine vision system
CO2	Explain various image enhancement and restoration techniques
CO3	Evaluate the techniques for image enhancement and image restoration
CO4	Interpret image segmentation and representation techniques

CO-PO Mapping:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	1	2	1	
CO2	3	1	1	2	1	
CO3	3	1	1	2	1	
CO4	3	1	1	2	1	

Skills Acquired

Design and implementation of vision based systems for automation applications.

Unit 1 15 Hours

Human Vision - Machine Vision and Computer Vision – HM, MVS camera -Analog, Digital- CID, CCD, CMOS, Camera Calibration - Frame Grabber, Manual & Auto shutter, Lighting parameters, Lighting sources, selection - Lighting Techniques - Type and selection, Digital camera Interfaces, Camera Computer Interfaces, Specifications and selection

Unit 2 15 Hours

Fundamentals of Digital Image-Filtering technique -Processing of binary and grey scale images-segmentation-thresholding-connectivity-noise reduction-edge detection-region growing and region splitting - binary and gray morphology operations. Feature extraction-Texture Analysis -Pattern recognition, image resolution-depth and volume, color processing, Template Matching -Decision Making, 3D Machine Vision Techniques

Unit 3 15 Hours

Automated visual inspection, In Vehicle vision sysems, image acquisition- caramas and digitization, sampling theorem, realtime hardware and system design considerations.

Applications of machine vision in Automotive Industries, Manufacturing, Electronics, Printing, Pharmaceutical, Biomedical, Robotics, Agricultural Applications

Text Books / References

1. E. R. Davies, *Computer and Machine Vision: Theory, Algorithms, Practicalities*, Academic Press, 2012
2. Rafael G Gonzalez and Richard E Woods, "*Digital Image Processing*", Pearson India, 2018.
3. Alexander Hornberg, "*Handbook of Machine and Computer Vision: The Guide for Developers and Users*", John Wiley & Sons, 2017.
4. Scott E Umbaugh, "*Digital Image Processing and Analysis: Applications with MATLAB and CVIP Tools*", CRC Press, 2017.

24MU634 **MOBILE ROBOTICS** **2-0-3-3**

Course Objectives

- Familiarize with essential elements of robotic locomotion.
- Comprehend challenges in realizing robotic locomotion.
- Familiarize with the concepts of path planning and navigation.
- Impart knowledge on the basics of robot learning and collective robotics.

Course Outcomes

CO	CO Description
CO1	Understand the concepts of mathematical models and motion control methods.
CO2	Apply various models of localization and navigation.
CO3	Analyse locomotion challenges and select motion planning algorithms
CO4	Design and develop autonomous mobile robots with obstacle avoidance

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	2	3		
CO2	3	2	2	2		
CO3	3	2	3	2	1	1
CO4	3	3	2	3	1	1

Skills Acquired

Design of wheeled robots, implementation of localization, mapping, and path planning algorithms.

Unit 1 **15 Hours**

Introduction to autonomous robotics, terrestrial and aerial locomotion, mobile robot kinematic models, manoeuvrability, workspace, and kinematic control. Perception – non-visual sensors and algorithms, computer vision, image processing, feature extraction – interest point detectors, range data.

Lab experiments

1. Design and simulation of a biped robot. 2. MATLAB/Python programming for kinematic control of differential drive vehicle. 3. Line fitting and range data feature extraction.

Unit 2 **15 Hours**

Mobile robot localization, Noise and aliasing, belief representation, probabilistic map-based localization – Markoc and Kalman filter localization, Autonomous map building, SLAM paradigms - Extended Kalman filter, graph-based and particle filter. Sensorial, geometric and topological maps, robot collectives – Sensing, communication, formation control, localization and mapping.

Lab experiments

1. Line-based Kalman filtering for mobile robot localization, 2. Simultaneous localization and mapping based on Extended Kalman Filtering.

Unit 3 **15 Hours**

Planning and Navigation: Path planning. Graph search – Voronoi diagram, deterministic graph search, Dijkstra's algorithm, A*, D* algorithm, Randomized graph search, Potential field path planning. Obstacle avoidance – Bug algorithm, Techniques viz. bubble band, curvature velocity, dynamic window approach, Schlegel approach, gradient method, etc., Mobile robots in practice, delivery robots, intelligent vehicles, mining automation, space robotics, underwater inspection, etc.

Lab experiments

1. Simulate a system of collective robots for arbitrary inputs and constraints, 2 Mobile robot path planning with global and local dynamic window approaches. 3. Noise rejection navigation simulation for mobile robot.

Text Books / References

1. Roland Siegwart, Illah R. Nourbakhsh, and Davide Scaramuzza. (2011). *Introduction to Autonomous Mobile Robots*. 2nd edition, The MIT Press.
2. Gregory Dudek, and Michael Jenkin. (2010). *Computational Principles of Mobile Robotics*. Second edition, Cambridge University press
3. Ulrich Nehmzow, (2012). *Mobile Robotics: A Practical Introduction Second Edition*. Springer.
4. Peter Corke (2017). *Robotics, Vision and Control Fundamental Algorithms in MATLAB®*. Second Edition. Springer
5. Howie Choset, Kevin Lynch, Seth Hutchinson, George Kantor, Wolfram Burgard, Lydia Kavraki, and Sebastian Thrun (2005) *Principles of Robot Motion Theory, Algorithms, and Implementation*, MIT press.
6. Sebastian Thrun, Wolfram Burgard, Dieter Fox. (2002) *Probabilistic Robotics*. The MIT press.
7. Steven M. LaValle. (2006). *Planning Algorithms*, Cambridge University Press.

24MU635 CYBER PHYSICAL SYSTEMS 3-0-0-3

Course Objectives

1. Introduce modeling of CPS
2. Introduce to analyze and simulate CPS systems

Course Outcomes

CO	CO Description
CO1	Understand the fundamentals of cyber-physical systems and analyze their design in different applications.
CO2	Apply modeling and associated tools for Hybrid system
CO3	Design of embedded systems for Cyber-Physical Systems (CPS), including sensors and actuators, embedded processors, memory architectures, Input/Output (I/O), multitasking, and scheduling
CO4	Analysis and verification for CPS and apply them in different domain applications

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	1	2	1	
CO2	3	1	1	2	1	
CO3	3	1	1	2	2	
CO4	3	1	1	2	2	

Skills Acquired

Implementation of CPS in manufacturing sector to realize the Industry 4.0

Unit 1 15 Hours

Introduction to Cyber-Physical Systems (CPS): Definition, features. CPS Application Domains: Introduction and Motivation, System Description, Operational Scenarios, Design Drivers and Attributes in Medical CPS, Energy CPS, CPS built on WSNs, Robotics and Autonomous Vehicles.

Unit 2 15 Hours

Modelling continuous dynamics behaviour - Actor models, properties of systems, feedback control. Modelling discrete dynamics behaviour - Finite State Machines, Extended State Machines. Hybrid systems - Classes and modal models. Composition of state machines, concurrent models of computation. Embedded Systems Design for Cyber-Physical Systems: Sensors and actuators, embedded processors, memory architectures, Input/Output, Multitasking, Scheduling.

Unit 3 15 Hours

Analysis and Verification of CPS: Invariants and temporal logic, equivalence and refinement, reachability analysis and model checking, quantitative analysis. Security of CPS: Introduction and Motivation, Attack Model and Counter Measures, System Theoretic Approaches.

Design and implementation of production lines through cyber physical systems in the manufacturing sector in industry 4.0 using machine learning, Recognition and Implementation of Cyber Physical Systems in the Development of Smart Factories in Industry 4.0 Through Optimization

Text Books / References

1. Lee EA, Seshia SA. "*Introduction to embedded systems: A cyber-physical systems approach*", MIT Press; 2017.
2. Alur R. "*Principles of cyber-physical systems*",MIT Press; 2015.
3. Rajkumar R, De Niz D, Klein M. "*Cyber-physical systems*",Addison-Wesley Professional; 2016.
4. G. Shanmugaraj, G. Sangeetha, G. Sethuram Rao, K. Mohanambal, "*A Review on Artificial Intelligence-Based Cyber Physical Systems for Industry 4.0*", IGIGI Global, 2023

24MU636 **SMART SENSORS** **3-0-0-3**

Course Objectives

1. To impart knowledge on smart sensing technology and its applications
2. To introduce the standards and protocols used for smart sensing

Course Outcomes

CO	CO Description
CO1	Select the suitable sesnsor for the given applicaiton
CO2	Design basic building blocks of a smart sesor
CO3	Demonstrate the understanding of miniaturized design of sensors in form of MEMS and NEMS
CO4	Understand the network architecture and communication protocols for sensor networks

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	1	2	2	
CO2	3	1	1	2	2	
CO3	3	1	1	2	2	
CO4	3	1	1	1	1	

Skills Acquired

Design of smart sensors and smart sensor network using advanced fabrication technologies

Unit 1 **15 Hours**

Sensor characteristics and physical principles of sensing – smart sensor system, example of smart sensors in nature (Vision –Hearing –touch -and smell) - Classification and Terminology of sensors – Measurands - Physical principles of sensing - electric charges – fields - and potentials Capacitance - magnetism - Induction – resistance - Piezoelectric effect - pyroelectric effect - Hall effect - Seebeck and Peltier effects. Smart sensor architecture, buses and interfaces, software, data acquisition and signal conditioning, electrical and non electrical variables, reliabilty of smart sensors.

Unit 2 **15 Hours**

Acoustic Sensors - Magnetic Sensors and Mechanical Sensors - Acoustic waves, piezoelectric materials - Acoustic sensing, -saw sensor - Sensor applications and future trends - Magnetic sensors - effects and materials -Integrated Hall sensors – Magneto-transistors - other magnetics transistor and future trends, Mechanical sensors - piezoresistivity - Piezoresistive sensors - Capacitive sensors. Radiation Sensors Thermal Sensors and Chemical Sensors - Radiation basics - HgCdTe infrared sensors - Visible-light color sensors - high-energy photodiodes - Heat transfer - thermal structures – Thermal sensing elements - Thermal and temperature sensors - Interaction of gaseous species at semiconductor Surfaces - Catalysis - the acceleration of chemical reactions - Thin-film sensors - FET devices for gas and ion sensing.

Unit 3 **15 Hours**

Micro-and Nanotechnologies or Sensors - Fundamentals of MEMS fabrication - introduction and description of basic processes - MEMS fabrication technologies - bulk micromachining - Surface micromachining - High-aspect-ratio (LIGA and LIGA-Like) technology microfluidics microsystem components Microfluidics microsystem components Nanotechnology - product prospects - application trends Procedures and techniques - the making of ultrathin films Creation of lateral nanostructures.

Communication protocols and sensor network standards, physical layer, MAC protocols, link layer, automotive protocols, routing protocols, IEEE 802.15.4, IEEE 802.11, IEEE 1451.2.

Text Books / References

1. Manabendra Bhuyan, "*Intelligent InstrumentationPrinciples and Applications*", Taylor and Francis, 2011.
2. Youn-Long Lin , Chong-Min Kyung , Hiroto Yasuura , Yongpan Liu , "*Smart Sensors and Systems*", Springer 2015.
3. Randy Frank, "*Understanding Smart Sensors*", Artech House, 2013.
4. Kofi Makinwa, GerardMeijer, Michiel Pertijs, "*Smart Sensor Systems: Emerging Technologies and Applications*", Wiley, 2014.

24MU637 **AUTOMOTIVE AUTOMATION** **3-0-0-3**

Course Objectives

- Introduce students to the various technologies and systems used to implement advanced driver assistance systems in vehicles
- Highlight impact of automation in various driving functions and connecting the automotive systems to sources of information that assist with a task.

Course Outcomes

CO	CO Description
CO1	Acquire knowledge on basics of how automotive ECUs function in conjunction with the vehicle data bus networks and sensors
CO2	Understand the concept of cyber-physical control systems and their application to collision avoidance and autonomous vehicles
CO3	Familiarize with the basic concepts of wireless communications and wireless data networks
CO4	Understand the fundamental principles of data networking and its roll in ADAS and future autonomous vehicles

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	1	2	2	
CO2	3	1	1	2	2	
CO3	3	1	1	2	2	
CO4	3	1	1	2	2	

Skills Acquired

Design of intelligent vehicles with advanced driverless and performance monitoring systems with sensors.

Unit 1 **15 Hours**

Concept of Automotive Electronics, Electronics Overview, History & Evolution, Infotainment, Body, Chassis, and Power-train Electronics, Advanced Driver Assistance Electronic Systems, Basic Control System Theory applied to Automobiles, Overview of the Operation of ECUs, Basic Cyber-Physical System Theory and Autonomous Vehicles, Role of Surroundings Sensing Systems and Autonomy, Basics of Radar Technology and Systems, Ultrasonic Sonar Systems, Lidar Sensor Technology and Systems, Camera Technology, Night Vision Technology, Other Sensors, Use of Sensor Data Fusion.

Unit 2 **15 Hours**

Wireless System Block Diagram and Overview of Components, Transmission Systems – Modulation/Encoding, Receiver System Concepts–Basics of Computer Networking – the Internet of Things, Wireless Networking Fundamentals, Connectivity Fundamentals, Navigation and Other Applications, Vehicle-to-Vehicle Technology and Applications, Vehicle-to-Roadside and Vehicle-to-Infrastructure Applications, Autonomous Vehicles - Driverless Car Technology, Moral, Legal, Roadblock Issues.

Unit 3 **15 Hours**

Basics of Theory of Operation, Applications, Integration of ADAS Technology into Vehicle Electronics, System Examples, Role of Sensor Data Fusion. Vehicle Prognostics Technology, Advanced Driver Assistance System Sensor Alignment and Calibration, Center Console Technology, Gauge Cluster Technology, Heads-Up Display Technology, and Warning Technology – Driver Notification. Impaired Driver Technology -Driver Impairment Sensor Technology, Sensor Technology for Driver Impairment Detection.

Text Books / References

1. Radovan Miucic, Connected Vehicles: *Intelligent Transportation Systems*, Springer, 2015 Intelligent
2. *Transportation Systems and Connected and Automated Vehicles*, Transportation Research Board 2016
3. Osseiran, Afif, Jose F. Monserrat, and Patrick Marsch, eds. *5G mobile and wireless communications technology*. Cambridge University Press, 2016.
4. Benevolo, Clara, Renata Paola Dameri, and Beatrice D'Auria. "*Smart mobility in smart city*." In Empowering Organizations, pp. 13-28. Springer, Cham, 2016.

STREAM 2: AI IN MANUFACTURING

24MU641 EXPLAINABLE AI FOR MANUFACTURING 3-0-0-3

Course Objectives

- Make students' understand the Explainable AI (XAI) techniques and their application in manufacturing. Students will learn the fundamentals of AI, explore its relevance in manufacturing processes,
- Familiarize on methods for ensuring transparency, interpretability, and accountability in AI models used in manufacturing environments.

Prerequisites

- Basic understanding of statistics, Familiarity with programming languages (e.g., Python) and basic knowledge of machine learning concepts

Course Outcomes

CO	CO Description
CO1	Understand the principles of AI and its applications in manufacturing
CO2	Explore the challenges of black-box AI models in manufacturing contexts
CO3	Implement various XAI techniques for improving model transparency and interpretability
CO4	Apply XAI techniques to real-world manufacturing datasets
CO5	Evaluate the trade-offs between model performance and interpretability in manufacturing scenarios

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	1	2		2
CO2	3	1	1	2		3
CO3	3	1	1	2		3
CO4	3	1	1	2		2
CO5	3	1	1	2		3

Skills Acquired

Implementation of AI concepts for the performance enhancement of manufacturing systems.

Unit 1 15 Hours

Introduction to AI in Manufacturing: Overview of AI and its applications in manufacturing, Challenges and opportunities of AI adoption in manufacturing, Case studies highlighting AI use cases in different manufacturing sectors. Fundamentals of Machine Learning: Basic concepts of machine learning, supervised, unsupervised, reinforcement learning, model evaluation metrics. Challenges of Black-Box AI Models: Lack of transparency and interpretability, Risks associated with black-box models in manufacturing, Regulatory requirements, and ethical considerations.

Unit 2 15 Hours

Explainable AI Techniques: Interpretable models (e.g., Decision Trees, linear models), Post-hoc explanations - SHapley Additive exPlanations (SHAP), Local Interpretable Model-agnostic Explanations (LIME), Rule-based systems, Model distillation, and simplification techniques. Interpretability in Deep Learning: Challenges of interpreting deep neural networks, Techniques for explaining deep learning models - layer-wise relevance propagation, Visualization methods for understanding deep learning processes. Applications of XAI in Manufacturing: Predictive maintenance and fault detection, Quality control and defect detection, Process optimization and scheduling, and Supply chain management.

Unit 3 **15 Hours**

Case Studies and Practical Applications: Hands-on exercises with XAI libraries in Python, analysis of real-world manufacturing datasets, and application of XAI techniques to solve manufacturing problems. Evaluation and Trade-offs: Quantitative and qualitative evaluation of XAI techniques, Trade-offs between model performance and interpretability, Strategies for selecting appropriate XAI methods based on application requirements, Future Directions and Emerging Trends: Advances in XAI research for manufacturing, Integration of XAI with autonomous systems and robotics, Ethical considerations and responsible AI practices in manufacturing.

Text Books / References

1. Molnar, Christoph. "*Interpretable machine learning. A Guide for Making Black Box Models Explainable*", 2019
2. Uday Kamath, and John Liu, "*Explainable Artificial Intelligence: An Introduction to Interpretable Machine Learning*", Springer, 2021, ISBN 9783030833558
3. Leonida Gianfagna and Antonio Di Cecco, "*Explainable AI with Python*", Springer International Publishing, First Edition, 2021
4. Denis Rothman, "*Hands-On Explainable AI (XAI) with Python*", Packt Publishing, First Edition, 2020

24MU642 DEEP REINFORCEMENT LEARNING 3-0-0-3

Course Objectives

1. Implement and use backpropagation algorithms to train deep neural networks
2. Apply regularization techniques to training deep neural networks
3. Apply optimization techniques to training deep neural networks

Course Outcomes

CO	CO Description
CO1	Understand the architecture and parameters involved in deep learning networks
CO2	Implement basic deep learning architectures.
CO3	Apply deep learning techniques to solve problems pertinent to signal and image processing in automation applications

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	1	2		3
CO2	3	1	1	2		3
CO3	3	1	1	2		3

Skills Acquired

Knowledge on deep learning networks, design of automation systems with deep reinforcement learning models for process optimization

Unit 1 15 Hours

Deep Learning: Artificial Neurons - the Building Blocks of Deep Learning, Feed-Forward Deep Neural Networks (DNN), Architectural Considerations in Deep Learning: Activation Functions in Deep Learning, Loss Functions in Deep Learning, Optimizers in Deep Learning: Gradient Descent and Error Back-Propagation, Stochastic Gradient Descent and Adaptive Learning Rate, Hyper-Parameter Selection, Regularization; Convolutional Neural Networks: Convolutional Layer, Pooling Layer, Flattened and Fully Connected Layers; Recurrent Neural Networks, LSTM, Deep learning examples.

Unit 2 15 Hours

Reinforcement Learning: Agents, environments, State and action, Reward, Reinforcement learning as a Markov Decision Process (MDP), Value Functions & Bellman Equations, Prediction and Control by Dynamic Programing, Monte Carlo Methods for Model Free Prediction and Control, Temporal difference learning, Function Approximation Methods, Policy Gradients., Applications in industrial automation and Robotics

Unit 3 15 Hours

Deep Reinforcement Learning Algorithms: Policy-based Algorithms, Value-based Algorithms, Model-based Algorithms, Combined Methods, On-policy and Off-policy Algorithms, Deep Reinforcement Learning for the automation and manufacturing applications.

Text Books / References

1. Ian Goodfellow, Yoshua Bengio and Aeron Courville, *Deep Learning*, MIT Press, First Edition, 2016.
2. Richard S. Sutton and Andrew G. Barto, *Reinforcement Learning: An Introduction*, 2nd Edition, The MIT Press, 2018
3. Hao Dong, Zihan Ding, and Shanghang Zhang, *Deep Reinforcement Learning: Fundamentals, Research and Applications*, Springer, 2020
4. Laura Graesser and Wah Loon Keng, *Foundations of Deep Reinforcement Learning: Theory and Practice in Python*, AddisonWesley, 2020
5. Sudharsan Ravichandiran, *Hands-On Reinforcement Learning with Python: Master reinforcement and deep reinforcement learning using OpenAI Gym and TensorFlow*, .2nd Edition, 2020.

24MU643 BIG DATA ANALYTICS FOR MANUFACTURING 3-0-0-3

Course Objectives

1. To provide an introduction to big data technologies and tools used for big data
2. Familiarize on the basics of relational databases and its implementation strategy using SQL are discussed in the first phase
3. Introduce on concepts of big data and its architecture, storage and processing of data in parallel and distributed system
4. Analyze unstructured data using NOSQL databases

Course Outcomes

CO	CO Description
CO1	Identify fundamental concepts of Databases and SQL
CO2	Apply SQL for data storage and retrieval
CO3	Explain fundamental concepts of Big Data and its technologies
CO4	Apply Map reduce programming for big data
CO5	Analyse appropriate NoSQL database techniques for storing and processing large volumes of structured and unstructured data

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	2			2
CO2	3	1	2	1		2
CO3	3	1	2	1		2
CO4	3	1	2	1		2
CO5	3	1	2	1		2

Skills Acquired

Data Visuvalization skills, programming and data mining skills, quantitative analysis and problem solving skills.

Unit 1 15 Hours

Introduction - Overview of DBMS - File vs DBMS - elements of DBMS - Relational Data Model - Introduction to relational model - Structure of relational mode – domain – keys - tuples to relational models - SQL – table creation - relationships - basic queries DML and DDL – Joins– Grouping.

Unit 2 15 Hours

Introduction to Big Data - Types of Digital Data - Characteristics of Data – Evolution of Big Data - Definition of Big Data - Challenges with Big Data-3Vs of Big Data -Terminologies in Big Data - CAP Theorem - BASE Concept – NoSQL - Types of Databases – Advantages – NewSQL - SQL vs. NOSQL vsNewSQL - Introduction to Hadoop - Features – Advantages – Versions.

Unit 3 15 Hours

Overview of Hadoop Eco systems - Hadoop distributions - Hadoop vs. SQL – RDBMS vs. Hadoop - Hadoop Components – Architecture – HDFS - Map Reduce: Mapper – Reducer - Map Reduce - Mapper – Reducer – Combiner – Partitioner - Hadoop 2 (YARN) - Architecture - Interacting with Hadoop Eco systems. No SQL databases - Cassandra: Introduction – Features - Data types – CQLSH - Key spaces - CRUD operations – Collections – Counter – TTL - Alter commands - Import and Export - Querying System tables.

Text Books / References

1. Seema Acharya, Subhashini Chellappa, "*Big Data and Analytics*", Wiley Publication, 2015.
2. Hurwitz JS, Nugent A, Halper F, Kaufman M. "*Big data for dummies*", John Wiley & Sons; 2013.
3. White T., "*Hadoop: The definitive guide*". O'Reilly Media, Inc."; 2012.
4. Bradberry R, Lubow E., "*Practical Cassandra: a developer's approach*", Addison-Wesley; 2013

24MU644 CYBER SECURITY IN MANUFACTURING 3-0-0-3

Course Objectives

- Provide fundamental knowledge on cloud based manufacturing, security challenges and risks associated with different cloud deployment models along with technologies necessary to protect manufacturing systems.
- Provide working knowledge of using different data mining techniques to identify cyber threats to a manufacturing system.
- Enable students to detect and prevent system intrusion, improve defense against targeted attacks and incident response, master modern technologies for security of machine tool systems and cyber-physical systems.

Course Outcomes

CO	CO Description
CO1	Develop technical expertise in security of cyber-physical systems and explore the security breaches.
CO2	Propose and assess the security solutions for cyber-physical systems.
CO3	Analyze and solve cyber security and system safety issues in cyber-physical systems
CO4	Create security metrics from the vulnerabilities, threats, risks and solutions for cyberphysical systems

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	1	2	1	
CO2	3	1	1	2	1	
CO3	3	1	1	2	1	
CO4	3	1	1	2	1	

Skills Acquired

Knowledge on security threads, design of CPS with network security features.

Unit 1 **15 Hours**

An overview of an industrial control system-the industrial control system architecture-the purdue model for industrial control systems- industrial control system communication media and protocols Industrial control system history-modbus and modbus TCP / IP – Profinet-Common IT protocols found in the ICS- Anatomy ICS attack scenario – Attacks-consequences-Risk assessment- Backend protocols-advanced metering infrastructure and smart grid-Industrial protocol simulators.

Unit 2 **15 Hours**

The converged plant wide Enterprise-The safety zone-the manufacturing zone-the enterprise zone-the CPwE industrial network security framework- Physical ICS security-ICS network security-ICS computer security-ICS Application security-ICS Device security - The ICS cyber security program development process. Introduction to industrial networking- common topologies- network segmentation-network services- Wireless networks-Remote access – performance considerations-safety instrumented systems-special considerations.

Unit 3 **15 Hours**

Consequences of successful cyber incident-cyber security and safety-common industrial targetscommon attack methods- Attack trends-industrial application layer attacks. Cyber security and risk management-methodologies for accessing risk within industrial control system-system characterization-threat identification-vulnerability identification-risk classification and ranking-risk reduction and mitigation. Cyber physical systems - Safety and security of cyber physical systems- Cyber-attacks and measures in cyber-physical systems - Cyber risks in industrial control systems - Costing security solutions -NERC CIP-CFATS-ISA/ IEC62443-mapping Industrial network security to compliance.

Text Books / References

1. Pascal Ackerman, "*Industrial Cyber security-Efficiently secure critical infrastructure systems*", Packt Publishing Ltd., Bringham, 2017.
2. Eric D.Knapp and Joel Thomas Langill, "*Industrial Network Security- Securing Critical Infrastructure Networks for smart Grid, SCADA, and other Industrial Control Systems*" Syngress is an Imprint of Elsevier, 2015.
3. Lihui Wang, Xi Vincent Wang, " *Cloud-Based Cyber –Physical systems in Manufacturing*", Springer Nature, 2018
4. Edward J.M. Colbert and Alexander Kott, "*Cyber-Security and SCADA and other Industrial control Systems*" Springer International Publishing AG Switzerland,2016

24MU645 **CLOUD COMPUTING** **3-0-0-3**

Course Objectives

- Introduce on the cloud computing fundamentals, including service and deployment models
- Make informed decisions when selecting and implementing cloud-based solutions for various projects and scenarios.
- Develop practical skills in managing and monitoring cloud deployments, focusing on orchestration, automation, and resource management

Course Outcomes

CO	CO Description
CO1	Understand the basic principles of cloud computing
CO2	Apply cloud machine learning platform to train machine learning models at scale, host trained model in the cloud, and use model to make predictions about new data.
CO3	Apply the cloud big data analysis framework to capture, manage, and process real-time data.
CO4	Apply cloud Artificial Intelligence platform and cloud cognitive services to build, deploy, and manage machine learning models.
CO5	Understand and apply Cloud dataflow models

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	2			1
CO2	3	1	2	1		3
CO3	3	1	2	1		3
CO4	3	1	2	1		3
CO5	3	1	2	1		3

Skills Acquired

Cloud store, manage, analyze, and skills required to build intelligent applications; Cloud computing tools and techniques to quickly build prototypes and eventually build applications.

Unit 1 **15 Hours**

Cloud Computing fundamentals - Principles of Cloud Computing Systems, Elastic Cloud Systems for Scalable Computing, Cloud Architectures Compared with Distributed Systems, Service Models, Ecosystems, and Scalability Analysis. Availability, Mobility, and Cluster Optimization; Cloud machine learning engine - cloud MLE train/deploy process, running single instance training and distributed training, hyper parameter tuning, Making predictions on cloud MLE, Batch prediction.

Unit 2 **15 Hours**

Data Collection, Mining, and Analytics on Clouds - Data quality control and representations, Data mining and data analytics on cloud, cloud resources for supporting Big data analytics; Cloud AI services - overview, Natural language Processing - Document Classification, summarisation, sentiment analysis, topic modelling and theme extraction, chatbots.

Unit 3 **15 Hours**

Understanding cloud language translation services, Analysing images with computer vision - Detecting objects and themes in images, image moderation, Facial analysis, text in images. Video Intelligence - Label detection, Operation status. Cloud Speech - synchronous and asynchronous Speech recognition, streaming speech recognition. Cloud dataflow – dataflow templates, data transformation with cloud dataflow. cloud publisher subscriber - architecture, message flow, implementation.

Text Books / References

1. Kai Hwang, "*Cloud Computing for Machine Learning and Cognitive Applications*", The MIT Press, 2017.
2. Ekaba Bisong, "*Building Machine Learning and Deep Learning Models on Google Cloud Platform*", Apress, 2019.
3. Anand Deshpande, Manish Kumar, Vikram Chaudhari, "*Hands-On Artificial Intelligence on Google Cloud Platform*", Packt Publishing, 2020
4. Jeffrey Jackovich, Ruze Richards, "*Machine Learning with AWS*", Packt Publishing, 2017.

STREAM 3: MANUFACTURING AND MANAGEMENT

24MU651 ADVANCED MANUFACTURING PROCESSES 3-0-0-3

Course Objectives

1. To familiarize the fundamentals of advanced casing processes and to understand the basic concepts of solidification.
2. To give exposure to various advanced welding techniques and to be familiarize with welding standards, weldability of different materials.
3. To select and apply various advanced machining processes for specific applications and to understand the optimization of parameters to obtain the desired machining quality.
4. To make students' understand the concepts of severe plastic deformation and High energy rate forming and to be familiarize with basics of stress strain relations and the deformation mechanisms.

Course Outcomes

CO	CO Description
CO1	Select and apply suitable advanced casting techniques to obtain the desired quality and to understand the concepts of solidification.
CO2	Perform suitable advanced welding techniques to obtain the desired weld joint and to understand the effect of welding parameters on weld quality.
CO3	Select and apply suitable advanced machining processes and optimize its parameters to achieve the desired machining characteristics.
CO4	Examine the stress strain relations and the deformation mechanisms and select appropriate severe plastic deformation and High energy rate forming processes to get the near net shape of the product.

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1	1	1		1
CO2	2	1	1	1		1
CO3	2	1	1	1	1	1
CO4	2	1	1	1	1	1

Skills Acquired

Ability to select the appropriate casting, welding processes, advanced machining processes, severe plastic deformation and high energy rate forming processes & to optimize its process parameters to obtain the desired quality.

Unit 1 12 Hours

Advanced Casting: Recap of conventional casting processes and casting metallurgy. Advanced casting processes: Continuous casting, Investment casting, Vacuum casting, Squeeze casting and Stir Casting, Directional solidification process. Rapid solidification processes - Foil strip and thin/micro casting, metallic glasses. Analysis of casting processes using software tools - Case studies.

Unit 2 12 Hours

Advanced Welding: Recap of conventional welding processes and welding metallurgy. Introduction to welding standards. Weldability of stainless steels, Cu, Al, Ti, Ni alloys, dissimilar materials, non-metallic materials. Advanced welding processes: Plasma Arc welding, Laser beam welding, Electron beam welding and solid-state welding processes. Micro welding, Analysis of welding processes using software tools - Case studies.

Unit 3 **12 Hours**

Advanced machining processes: Electric Discharge Machining - Abrasive Jet Machining - Abrasive Water Jet Machining. Laser Beam machining and drilling. Laser cutting, Plasma Arc machining and Electron Beam Machining. Metal removal mechanisms, applications and case studies.

Unit 4 **9 Hours**

Advanced forming processes: Stress strain relations in elastic and plastic deformation - concept of flow stress determination - deformation mechanisms. Severe plastic deformation and High energy rate forming-Electro-magnetic forming, explosive forming, Hydro forming, Electro-hydraulic forming, Stretch forming, Contour roll forming and roll bonding. Applications and case studies.

Text Books / References

1. Yu, K.O., *"Modelling for Casting and Solidification Processing",* Marcel Dekker, 2002.
2. Sindo Kou, *"Welding Metallurgy",* Second Edition, John Wiley Publications, New York, 2003.
3. Jain V.K., "Advanced Machining Processes", Allied Publishers Pvt. Ltd., NewDelhi, 2007.
4. Hassan Abdel-Gawad El-Hofy "*Advanced Machining Processes / Non Traditional and Hybrid Machining Processes",* McGraw-Hill Education, First Edition, 2005.
5. G.F. Benedict, Marcel Dekker, *"Non-traditional Manufacturing Processes"*, Marcel Dekker, 1987.
6. E. P. DeGarmo, J. T Black, R. A. Kohser, *"Materials and Processes in Manufacturing",* 10th Edition, John Wiley & Sons, 2008.
7. Henry S.Valberg., *"Applied Metal Forming",* Cambridge University Press, 2012.
8. Wagoner, R. H. and Chenot, J. L., *"Metal Forming Analysis"*, Cambridge University Press, 2005.

24MU652 INTELLIGENT MANUFACTURING SYSTEMS 3-0-0-3

Course Objectives

- To provide fundamental concepts on intelligent manufacturing system (IMS) to achieve flexible, smart, and reconfigurable manufacturing processes.
- To familiarize various supporting technologies required to implement IMS.

Course Outcomes

CO	CO Description
CO1	Understand the concepts of intelligent manufacturing systems.
CO2	Integrate the various elements of manufacturing system for implementation of IMS.
CO3	Select suitable supporting technologies to enable IMS implementation.
CO4	Identify the real time issues in implementations of IMS with suitable case studies

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	2	2	1	
CO2	3	1	2	2	1	
CO3	3	1	2	2	1	
CO4	3	1	2	2	1	

Skills Acquired

Ability to implement intelligent manufacturing systems concepts in an industry to improve the performance measures.

Unit 1 15 Hours

Introduction to Manufacturing systems, various subsystems in manufacturing systems, procurement, design, manufacturing, inspections, assembly, prototyping, material handling, storage systems, concept of Intelligent manufacturing: Internet of Things enabled manufacturing, cloud manufacturing. Characteristics of Intelligent manufacturing systems: Intelligent decision making, Application of Artificial Intelligence and Machine learning in developing intelligent manufacturing systems.

Unit 2 15 Hours

Component of Intelligent Manufacturing Technologies, Development of Intelligent systems for Design, Process planning, Controls, Scheduling, Quality Management, Maintenance and Diagnostics. Supporting technologies for IMS: Industry Internet of Things, Cyber Physical Systems, Cloud computing, RFID Technologies, Data Analytics, other Information and Communications Technology.

Unit 3 15 Hours

Framework for intelligent manufacturing: Smart design, Smart machines, Smart control, Smart scheduling, Human-Machine collaboration, collaborative robots and other enabling technologies such as AR and VR, Data-driven intelligent manufacturing models, Autonomous intelligent manufacturing units. Applications and case studies in intelligent manufacturing systems implementation, limitation of technologies and other real time issues in implementations of IMS.

Text Books / References

1. Andrew Kusiak, *Intelligent Manufacturing Systems*, Prentice Hall international series- industrial & systems engineering, 1990. I
2. *Intelligent Manufacturing in the Context of Industry 4.0: A Review*, Engineering, Elsevier Publications, Volume 3, Issue 5, October 2017, Pages 616-630.
3. Peigen Li, Special Issue: *Intelligent Manufacturing, Engineering*, Elsevier Publications, 3, 2017, 575.
4. Yubao Chen, *Integrated and Intelligent Manufacturing: Perspectives and Enablers*, Engineering 3, 2017, Pages 588–595.
5. Hamid R. Parsaei and Mohammad Jamshidi, *Design and Implementation of Intelligent Manufacturing Systems: From Expert Systems, Neural Networks, to Fuzzy Logic*, Prentice Hall Series Publication, 1995.
6. Jongwon Kim, *Manufacturing Systems 1997 - IFAC Proceedings* Volumes, Elsevier publications, 1997.

24MU653 MODELING AND SIMULATION OF MANUFACTURING SYSTEMS 2-0-3-3

Course Objectives

- To make the students proficient in the use of discrete event simulation software for modeling and simulation of the manufacturing system.
- Expose students to model real-world manufacturing systems
- Analyze any manufacturing system for improvement using a discrete event simulation package.

Course Outcomes

CO	CO Description
CO1	Appreciate the role of discrete-event simulation and modeling and their application in the manufacturing environment.
CO2	Analysis of simulation input data using statistical tools and fit the input data into a suitable probability distribution for developing simulation models of manufacturing systems.
CO2	Model and analyze complex manufacturing systems using discrete event simulation software package.
CO4	Interpret and analyze the simulation results of a real-world problem, identify bottlenecks, and provide suggestions for performance improvement.

CO-PO Mapping:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2		2	1		
CO2	2	3	2	2		
CO3	2	3	2	2		
CO4	2	3	2	2		1

Skills Acquired

Performance Modelling of Manufacturing Systems using Discrete Event Simulation Software; Bottleneck analysis

Unit 1 **15 Hours**

Concept of System and environment, Continuous and discrete systems, Linear and non-linear systems, Stochastic processes, Static and Dynamic models, Principles of modelling, Basic Simulation modelling, Role of simulation in model evaluation and studies, Steps in a simulation study, Verification, validation and credibility of simulation models, Advantages, disadvantages and pitfalls of simulation, Review of probability distributions and basic statistics.

Unit 2 **15 Hours**

Definition, Classifications and characteristics of production systems; measures of manufacturing systems performance, modelling elements in manufacturing systems; processes, resources, single and multi-server queues, arrival processes, service times, downtime, manufacturing costs, resources selection rules, different manufacturing flexibilities. Input data modelling - Basic DES Modelling, Manufacturing Performance Metrics in DE, Modelling basic and detailed operations: part arrivals, sequencing, and scheduling, resources/processes, transporters, material handling, inventory management, inspection

Unit 3 **15 Hours**

Simulation output analysis – Bottleneck analysis – Sensitivity Analysis - Simulation Optimization – Exercise / Case problems: Modelling and analysis of Flow shops, Job shops, Flexible Manufacturing Systems, Push / Pull manufacturing systems, Supply Chains using discrete event simulation package.

Text Books / References

1. Kelton, W. David. "*Simulation with ARENA*". McGraw-Hill, 2015.
2. Altiok, Tayfur, and Benjamin Melamed. "*Simulation modeling and analysis with Arena*". Elsevier, 2010.
3. Rossetti, Manuel D. "*Simulation modeling and Arena*". John Wiley & Sons, 2015.
4. Lab Manual

24MU654 OPTIMIZATION TECHNIQUES IN ENGINEERING 2-0-3-3

Course Objectives

- Introduce the traditional and modern methods of optimization techniques used for solving non-linear unconstraint and constraint engineering optimization problems.
- Considering the computational aspects, the course will involve a significant number of computational assignments using software tools and a term project in the area of engineering optimization.

Course Outcomes

CO	CO Description
CO1	Formulate the engineering problems as an optimization problem
CO2	Apply necessary and sufficient conditions for a given optimization problem for optimality
CO3	Select appropriate solution methods and strategies and solve optimization problems
CO4	Justify and apply the use of modern heuristic methods for solving complex optimization problems to obtain optimal / near-optimal solution
CO5	Interpret and analyze the solution obtained by optimization algorithms and improve their convergence and solution quality
CO6	Solve Engineering Design and Manufacturing related optimization problems using software tools.

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	2			
CO2	3	2	2	1		
CO3	3	2	2			
CO4	3	2	2	1		2
CO5	3	2	2	1		2
CO6	3	2	2	1		

Skills Acquired

Formulate the engineering problems as an optimization problem; Select appropriate solution methods and strategies and solve optimization problems; Solving complex optimization problems using heuristic/ meta heuristic approach; Solve Engineering Design and Manufacturing related optimization problems using software tools.

Unit 1 **10 Hours**

Introduction to Optimization - Engineering applications - Statement of an optimization problem - Classification - Optimal problem formulation: Problems in design and manufacturing fields - Optimality criteria - Classical optimization techniques - Kuhn-Tucker (KT) optimality conditions.

Unit 2 **10 Hours**

Non-linear programming algorithms: One-dimensional problem, Unconstrained optimization problem, Constrained optimization problem - Transformation methods - Interior and exterior penalty function method - Convergence and divergence of optimization algorithms - Complexity of algorithms.

Unit 3 **10 Hours**

Modern Methods in Optimization: Genetic Algorithm - Simulated Annealing - Particle Swarm Optimization - Neural Network-based optimization - Optimization of Fuzzy systems - Multi-Objective optimization – Optimization in the probabilistic domain - Shape and Topology optimization - Data Analytics and optimization using Machine learning approach.

Lab Practice **12 Sessions**

Implementing optimization algorithm using software tools / Programming for solving Engineering Design / Manufacturing related problems

- Checking the optimality of unconstraint and constraint optimization problems using the Hessian matrix.
- Solving Linear, Mixed Integer, Quadratic, Non-Linear Unconstrained, and Constrained optimization problems using direct and gradient-based algorithms.
- Implementing Modern methods of optimization namely GA, SA, and PSO for solving large scale linear and complex non-linear optimization problems
- Statistical modeling and Parameter optimization
- Multi-objective optimization using Evolutionary Multi-Objective Optimization algorithms
- Case studies / Project / Presentation / Report writing: Optimal design of real-world engineering problems

Text Books / References

1. Rao, Singiresu S. "*Engineering optimization: theory and practice*". John Wiley & Sons, 2019.
2. Deb, Kalyanmoy. "*Optimization for engineering design: Algorithms and examples*". PHI Learning Pvt. Ltd., 2012.
3. Arora, J.S., "*Introduction to Optimum Design*", Academic Press, 4th Edition, 2017.

24MU655 PRODUCT LIFECYCLE MANAGEMENT 3-0-0-3

Course Objectives

1. To expose the components of product life cycle management.
2. To develop structure and effectiveness of configuration management.
3. To describe various types of project flows and role assignments.
4. To make students' understand the issues related to change management.
5. To familiarize on the configuration of product and data management.

Course Outcomes

CO	CO Description
CO1	Identify components of PLM/PDM
CO2	Evaluate the structure of configuration management.
CO3	Create project work flows and assign roles.
CO4	Analyze issues in change management.
CO5	Develop product configurations and manage the data.

CO-PO mapping

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1					
CO2	1	2				
CO3	1	2		2		
CO4	1		2	2		
CO5	1	2	2			

Skills Acquired

Know about digitally connected enterprise and operational complexity, business process optimization

Unit 1 15 Hours

Introduction to Product life cycle - PLM- PDM concepts -present market constraints - need for collaboration – Object oriented programming concepts - internet and developments in server - client computing. Components of a typical PLM / PDM setup - hardware and software - document management - creation and viewing of parts and documents-version control -case studies. Configuration management: Base lines - product structure - configuration management – Effectivity - case studies.

Unit 2 15 Hours

Creation of projects and roles - life cycle of a product- life cycle management - automating information flow-workflows - creation of work flow templates -life cycle - work flow integration - case studies. Change management: Change issue-change request- change investigation- change proposal - change activity - case studies.

Unit 3 15 Hours

Generic products and variants: Data Management Systems for FEA data - Product configuration - comparison between sales configuration and product configuration -generic product modeling in configuration model - use of order generator for variant creation-registering of variants in product register-case studies. Implementation issues and best practices.

Text Books / References

1. Kevin Otto and Kristin Wood, "*Product Design*", Pearson, 2001.
2. Daniel Amor, "*The E-Business Revolution*", Prentice Hall, 2000.
3. David Bed Worth, Mark Henderson, and Phillip Wolfe, "*Computer Integrated Design and Manufacturing*", McGraw Hill, 1991.
4. Terry Quatrain., "*Visual Modeling with Rational Rose and UML*", Addison Wesley, 1998.
5. Antti Saaksvuori and Anselmi Immonen, "*Product Life Cycle Management*", Second Edition, Springer, 2005.

24MU656 LOGISTICS AND SUPPLYCHAIN MANAGEMENT 3-0-0-3

Course Objectives

- To expose the complexities and key issues in supply chain management.
- To develop location models, logistics networks, traveling salesman and vehicle routing and scheduling models.
- To analyze the inventory models, strategic alliances, role of information and integration in supply chain.
- To understand the issues related to global supply chains, procurement and outsourcing, product chain design and customer value.
- To understand advanced topics in supply chain related to Industry 4.0 and sustainability.

Course Outcomes

CO	CO Description
CO1	Analyze the complexity and key issues in supply chain management
CO2	Evaluate single and multiple facility location problems, logistics network configuration, vehicle routing and scheduling models.
CO3	Analyze inventory models, dynamics of supply chain and role of information in supply chain.
CO4	Develop the appropriate supply chain through strategic alliances and supply chain integration.
CO5	Identify the issues in global supply chains, procurement, outsourcing, product chain design and customer value.
CO6	Develop models in Logistics 4.0, digital supply chains, sustainable supply chains, urban logistics and humanitarian logistics.

CO-PO mapping

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1		1			
CO2	1	2	3	3		1
CO3	1	2	3	3	1	1
CO4	1		2		1	
CO5	1		3			
CO6	1	1	2	3		1

Skills Acquired

Analyze key issues in supply chain management and develop models and solutions

Unit 1 **15 Hours**

Introduction: Introduction to SCM-the complexity and key issues in SCM. Location strategy – facility location decisions – single facility and multiple location models.Inventory strategy: Inventory Management and risk pooling-managing inventory in the SC.

Logistics: Logistics Network Configuration – data collection – data aggregation – Inventory Positioning and Logistics Coordination, Traveling salesman problems – exact and heuristic methods, Vehicle routing and scheduling – guidelines – problems.

Unit 2 **15 Hours**

The value of information - bullwhip effect -information sharing and incentives - lead time reduction. Supply chain integration: Supply chain integration-distributed strategies-push versus pull systems. Strategic alliances-third party logistics-retailer–supplier partnerships - distribution integration.

Unit 3 **15 Hours**

Issues in SCM: Procurement and outsourcing strategies – framework of eprocurement. International issues in SCM-regional differences in logistics. Coordinated product and supply chain design-customer value and SCM.

Advances in supply chain: Logistics 4.0, Digital supply chains, Sustainable supply chains, Urban logistics, Humanitarian logistics.

Text Books / References

1. David Simchi-Levi and PhlipKamainsky, *"Designing and Managing the Supply Chain: Concepts, Strategies, and Cases*", McGraw Hill, 2002.
2. Martin Christopher, *"Logistics and Supply Chain Management: Strategies for Reducing Cost and Improving Service",* Prentice Hall, 1999.
3. Ronald Ballou, *"Business Logistics / Supply Chain Management*", Pearson Education, 2003.
4. Thomas E. Vollmann, Willan L. Bery, Robert Jacobs, F., and David Clay Bark, *"Manufacturing Planning and Control for Supply Chain Management",* Fifth Edition, McGraw Hill, 2005.

24MU657 **RELIABILITY ENGINEERING** **3-0-0-3**

Course Objective

Provide the importance of reliability, the basic methods to evaluate product and system reliability

Course Outcomes

CO	CO Description
CO1	Determine the reliability of a product by applying the knowledge of probabilistic concept.
CO2	Identify and select the various failure models
CO3	Identify and select different reliability testing methods
CO4	Predict the reliability of a product using failure data.

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	2	2		
CO2	3	1	2	2		
CO3	3	1	2	2		
CO4	3	1	2	2		

Skills Acquired

Ability to determine reliability of a system and to identify suitable testing methods for industrial applications

Unit 1 **15 Hours**

Concept and Definition of reliability (reliability mathematics)-Failure distributions, hazard models – exponential, Rayleigh, Weibull, Normal and Lognormal distributions -MTTF, MTBF. Reliability of systems – series and parallel configurations - Reliability improvement, redundancy, k-out-of-n system -Reliability of complex configurations-Reliability of three-state devices – Markov analysis-Physical reliability models – random stress and random strength-

Unit 2 **15 Hours**

Design for reliability-Reliability allocation, derating-Maintainability-Design for maintainability-Availability-Maintenance and space provisioning. Failure data analysis-Reliability Testing-Identifying failure distributions–parameter estimation.

Approaches to intelligent control- AI approach- Concept of artificial neural network and its model, fuzzy logic and its model- Case study

Text Books / References

1. Charles Ebeling, "*An introduction to Reliability and Maintainability Engineering*", Tata McGraw Hill, 2000.
2. Lewis E. E., "*Introduction to Reliability Engineering*", Second Edition, John Wiley & Sons, 1995.
3. Rao S. S., "*Reliability Based Design*", McGraw Hill, 1992.
4. Srinath L.S., "*Mechanical Reliability*", East-West Press,2002.
5. Simon Haykins, "*Neural network : A comprehensive foundation*", Pearson Edition, 2003
6. T. J. Ross, "*Fuzzy logic with fuzzy application*",McGrawHill, 1997.

24MU658 ADVANCES IN MATERIALS SCIENCE AND CHARACTERISATION 3-0-0-3

Course Objectives

- To familiarize the fundamentals of thermodynamics of nucleation and kinetics of growth.
- To select appropriate materials and manufacturing techniques to meet end applications.
- To understand the benefits of high-performance energy materials and its fabrication route.
- To provide materials' structure and its properties with the aid of advanced characterization techniques.

Course Outcomes

CO	CO Description
CO1	Gain knowledge about thermodynamics of nucleation and strengthening mechanisms
CO2	Analyse (and select) suitable materials and methods to meet high end and light weight application
CO3	Acquire knowledge in high performance materials and techniques
CO4	Analyse interrelationships and interdependence between processing, structure, properties, and performance using advanced material characterization techniques

CO-PO Mapping:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1		2	2			
CO2	2	2	2		3	
CO3	2	2	2		3	
CO4	2	2	2	1	1	

Skills Acquired

Concept of advanced materials science and its characterization up to the atomic level, Difference between conventional and advanced materials, Thermodynamics and equipment details for advanced materials.

Unit 1 15 Hours

Introduction to advanced materials science, thermodynamics of homogeneous and heterogeneous nucleation and kinetics of growth, non-equilibrium freezing, segregation, nucleation in the solid state, diffusion in solids, strengthening mechanism and principles. Material science and processing of light materials- aluminium, titanium, high strength steel, magnesium alloys, super alloys, high temperature materials, ceramic and carbon composites, cellular solids, metal foams.

Unit 2 15 Hours

Processing of nano, bio and composite materials and their manufacturing science, high performance polymers, recent advances in material development- functionally gradient materials and characterization, carbon nanostructures, graphenes, fullerenes, next generation battery and fuel cell materials. Introduction to special processes- High energy ball milling, thin films and vapour depositions, laser and other high intensity beam processes, sol-gel technique, synthesis and additive manufacturing.

Unit 3 15 Hours

Introduction to advanced materials characterization techniques-Scanning electron microscopy, transmission electron microscopy and energy dispersive analyses, X-ray diffraction, atomic force microscopy, Fourier-transform infrared spectroscopy, Field array NDT techniques for futuristic materials.

Challenges and scope for new and advanced materials, case studies related to design-materials selection – manufacturing models.

Text Books / References

1. Bhushan Bharat, *“Springer Handbook of Nanotechnology”*, Springer, 2017
2. Rowe Jason, *“Advanced Materials in Automotive Engineering”*, Woodhead Publishing, 2016.
3. Cao Guozhong, *“Nanostructures & Nanomaterials: Synthesis, Properties & Applications”*, Imperial College Press, 2004.
4. Michio Inagaki Feiyu Kang Masahiro Toyoda Hidetaka Konno, *“Advanced Materials Science and Engineering of Carbon”*, 1st Edition, Butterworth-Heinemann, 2013, ISBN: 9780124077898
5. Gaskell, David R*., “Introduction to Metallurgical Thermodynamics”*, McGraw Hill, 1973
6. W. D. Callister, *"Materials Science and Engineering: An Introduction"*, John Wiley & Sons, 2007.
7. C. Kittel, *"Introduction to Solid State Physics"* , Wiley Eastern Ltd, 2005.
8. Sam Zhang, Lin Li and Ashok Kumar*, “Materials Characterization Techniques”*, CRC Press, (2008)

24MU659 LEAN MANUFACTURING 3-0-0-3

Course Objectives

- To impart knowledge on basic concepts of lean manufacturing to continuously improve the productivity
- To familiarize lean tools for improvement and integrate them with the organization's strategies to personalize the lean process.

Course Outcomes

CO	CO Description
CO1	Identify key requirements and concepts in lean manufacturing.
CO2	Initiate a continuous improvement change program in a manufacturing organization.
CO3	Analyze and improve a manufacturing system by applying lean manufacturing tools
CO4	To achieve lean six sigma quality and sustainability in a manufacturing system

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	2	1		
CO2	2			2	1	
CO3	2	2	2	1	1	
CO4	2	2	2	2		

Skills Acquired

Capability to understand the value stream and non-value addition of a manufacturing/business system, To apply the concepts of TAKT TIME, To practice KAIZEN concept in manufacturing systems. Students can get a lean certification and do work independently as consultants.

Unit 1 15 Hours

Lean Manufacturing - Introduction - History of Lean – Toyota Production System- comparison to other methods - The 7 Wastes, their causes and the effects – An overview of Lean Principles / concepts / tools - Toyota Production System, Tools of Lean Manufacturing- Continuous Flow - Continuous Flow Manufacturing and Standard Work Flow - 5S and Pull Systems (Kanban and ConWIP systems) - Error Proofing and Set-up Reduction – Total Productive Maintenance (TPM) - Kaizen Event examples. - Ford Production Systems, Value Stream Mapping – Current state and Future State. Building a Current State Map, Key issues in building the Future State Map - Process tips in building the map and analysis of the customer loop, supplier loop, manufacturing loop and information loop - Example of completed Future State Maps, Sustainable value stream mapping, Assessment of economical, environmental and social dimentions of sustainability –VSM 4.0 and information logistics, determine the wastes in information flow- Implementation of lean practices - Best Practices in Lean Manufacturing. Six Sigma Fundamentals -Selecting Projects – Six Sigma Statistics - DMAIC – Define, Measure, Analyze, Improve, Control. Lean Six Sigma – Four Keys to Lean Six Sigma - Delight Your Customers with Speed and Quality Improve Your Processes, Work Together for Maximum Gain, Base Decisions on Data and Facts - Five Laws of Lean Six Sigma - Case Studies.

Unit 2 15 Hours

Ergonomics-as enabler of lean manufacturing, Ergonomic consideration at work, Principles related to: the use of human body, the arrangement of workplace, the design of tools and equipment

Unit 3 15 Hours

The impact of Industry 4.0 on soft lean practices, The facilitating effects of lean manufacturing on Industry 4.0 implementation, Effect of environmental factors on the integration of Industry 4.0 and lean manufacturing, Study on the performance implications of Industry 4.0 and lean manufacturing integration.

Text Books / References

1. James P. Womack, Daniel T. Jones, and Daniel Roos, "T*he Machine that Changed the World: the Story of Lean Production*", Simon & Schuster, 1996.
2. Jeffrey K. Liker, "*Becoming Lean*", Industrial Engineering and Management Press, 1997.
3. James P. Womack and Daniel T. Jones, "*Lean Thinking*", Free Press-Business and Economics, 2003.
4. Rother M. and Shook J., "*Learning to See*", The Lean Enterprise Institute, Brookline, 2003.
5. George, Michael. L. "*Lean six sigma: combining six sigma quality with lean speed*", Tata McGraw Hill Education, New Delhi, 2002.
6. Larson, Alan, "*Demystifying six sigma : a company-wide approach to continuous improvement*", Jaico, Mumbai, 2007.
7. Barnes, R, "*Motion and Time Study*" - Design and Measurement of Work. NY: John Wiley and Sons, 8th Edition, 1985.

22AVP103 Mastery Over Mind (MAOM) 1-0-2 2

1. Course Overview

Master Over the Mind (MAOM) is an Amrita initiative to implement schemes and organise university-wide programs to enhance health and wellbeing of all faculty, staff, and students (UN SDG -3). This program as part of our efforts for sustainable stress reduction gives an introduction to immediate and long-term benefits and equips every attendee to manage stressful emotions and anxiety facilitating inner peace and harmony.

With a meditation technique offered by Amrita Chancellor and world-renowned humanitarian and spiritual leader, Sri Mata Amritanandamayi Devi (Amma), this course has been planned to be offered to all students of all campuses of AMRITA, starting off with all first years, wherein one hour per week is completely dedicated for guided practical meditation session and one hour on the theory aspects of MAOM. The theory section comprises lecture hours within a structured syllabus and will include invited guest lecture series from eminent personalities from diverse fields of excellence. This course will enhance the understanding of experiential learning based on university's mission: "Education for Life along with Education for Living", and is aimed to allow learners to realize and rediscover the infinite potential of one's true Being and the fulfilment of life's goals.

2. Course Syllabus

Unit 1 (4 hours)

Causes of Stress: The problem of not being relaxed. Need for meditation -basics of stress management at home and workplace. Traditions and Culture. Principles of
meditation– promote a sense of control and autonomy in the Universal Human Value System. Different stages of Meditation. Various Meditation Models. Various practices of Meditation techniques in different schools of philosophy and Indian Knowledge System.

Unit 2 (4 hours)

Improving work and study performance. Meditation in daily life. Cultivating compassion and good mental health with an attitude of openness and acceptance. Research and Science of Meditation: Significance of practising meditation and perspectives from diverse fields like science, medicine, technology. philosophy, culture, arts, management, sports, economics, healthcare, environment etc. The role of meditation for stress and anxiety reduction in one's life with insights based on recent cutting-edge technology. The effect of practicing meditation for the wholesome wellbeing of an individual.

Unit 3 (4 hours)

Communications: principles of conscious communication. Relationships and empathy: meditative approach in managing and maintaining better relationships in life during the interactions in the world, role of MAOM in developing compassion, empathy and responsibility, instilling interest, and orientation to humanitarian projects as a key to harness intelligence and compassion in youth. Methodologies to evaluate effective awareness and relaxation gained from meditation. Evaluating the global transformation through meditation by instilling human values which leads to service learning and compassion driven research.

TEXT BOOKS:

1.Mata Amritanandamayi Devi, "Cultivating Strength and vitality," published by Mata Amritanandamayi Math, Dec 2019

2.Swami Amritaswarupananda Puri ,"The Color of Rainbow " published by MAM, Amritapuri.

REFERENCES:

1.Craig Groeschel, "Winning the War in Your Mind: Change Your Thinking, Change Your Life" Zondervan Publishers, February 2019

2.R Nagarathna et al, "New Perspectives in Stress Management "Swami Vivekananda Yoga Prakashana publications, Jan 1986

3. Swami Amritaswarupananda Puri "Awaken Children Vol 1, 5 and 7 - Dialogues with Amma on Meditation", August 2019
4. Swami Amritaswarupananda Puri "From Amma's Heart - Amma's answer to questions raised during world tours" March 2018
5. Secret of Inner Peace- Swami Ramakrishnananda Puri, Amrita Books, Jan 2018.

6. Mata Amritanandamayi Devi “Compassion :The only way to Peace:Paris Speech”, MA Center, April 2016.
7. Mata Amritanandamayi Devi “Understanding and collaboration between Religions”, MA Center, April 2016.
8. Mata Amritanandamayi Devi “Awakening of Universal Motherhood: Geneva Speech” M A center, April 2016.

3. Evaluation and Grading

Internal			External	Total
Components	Weightage		Practical (attendance and class participation) 60%	100%
Quizzes(based on the reading material)	20%	40%		
Assignments (Based on webinars and lecture series)	20%			

4. Course Outcomes (CO)

CO1: Relate to the causes of stress in one’s life.
CO2: Experiment with a range of relaxation techniques
CO3: Model a meditative approach to work, study, and life.
CO4: Develop appropriate practice of MA-OM technique that is effective in one’s life
CO5: Inculcate a higher level of awareness and focus.
CO6: Evaluate the impact of a meditation technique

*__Program Outcomes (PO) (As given by NBA and ABET)__
PO1: Engineering Knowledge
PO2: Problem Analysis
PO3: Design/Development of Solutions
PO4: Conduct Investigations of complex problems
PO5: Modern tools usage
PO6: Engineer and Society
PO7: Environment and Sustainability
PO8: Ethics
PO9: Individual & Team work
PO10: Communication
PO11: Project management & Finance
PO12: Lifelong learning

CO – PO Affinity Map

P O/ C O	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PS01	PSO2	PSO3
CO 1	3	3	3	2		-	2	3	-	3	-	3	-	-	-
CO 2	3	3	3	2	2	_	2	3	3	3	-	3	-	-	-
CO 3	3	3	2	2	2	2	2	3	3	3	-	3	-	-	-
CO 4	3	3	3	2	-	2	3	3	3	3	-	3	-	-	-
CO 5	3	2	2	2	-	2	-	3	2	2	-	2	-	-	-
CO 6	3	2	2	2	3	2	_	3	2	2	-	2	-	-	-

23HU601	Career Competency I	L-T-P-C: 0-0-3-P/F

Prerequisite:
An open mind and the urge for self-development, basic English language skills and knowledge of high school level arithmetic.

Course Objectives:

- Help students transit from campus to corporate and enhance their soft skills
- Enable students to understand the importance of goal setting and time management skills
- Support them in developing their problem solving and reasoning skills
- Inspire students to enhance their diction, grammar and verbal reasoning skills

Course Outcomes:
CO1: Soft Skills - To develop positive mindset, communicate professionally, manage time effectively and set personal goals and achieve them.
CO2: Soft Skills - To make formal and informal presentations with self-confidence.
CO3: Aptitude - To analyze, understand and employ the most suitable methods to solve questions on arithmetic and algebra.
CO4: Aptitude - To analyze, understand and apply suitable techniques to solve questions on logical reasoning and data analysis.
CO5: Verbal - To infer the meaning of words and use them in the right context. To have a better understanding of the nuances of English grammar and become capable of applying them effectively.
CO6: Verbal - To identify the relationship between words using reasoning skills. To understand and analyze arguments and use inductive/deductive reasoning to arrive at conclusions and communicate ideas/perspectives convincingly.

CO-PO Mapping

PO/CO	PO1	PO2	PO3
CO1	2	1	-
CO2	2	1	-
CO3	2	1	-
CO4	2	1	-
CO5	1	2	-
CO6	2	2	-

Syllabus:
Soft Skills
Introduction to ‘campus to corporate transition’:
Communication and listening skills: communication process, barriers to communication, verbal and non-verbal communications, elements of effective communication, listening skills, empathetic listening, role of perception in communication.
Assertiveness skills: the concept, assertiveness and self-esteem, advantages of being assertive, assertiveness and organizational effectiveness.
Self-perception and self-confidence: locus of control (internal v/s external), person perception, social perception, attribution theories-self presentation and impression management, the concept of self and self-confidence, how to develop self-confidence.
Goal setting: the concept, personal values and personal goals, goal setting theory, six areas of goal setting, process of goal setting: SMART goals, how to set personal goals
Time management: the value of time, setting goals/ planning and prioritizing, check the time killing habits, procrastination, tools for time management, rules for time management, strategies for effective time management
Presentation skills: the process of presentation, adult learning principles, preparation and planning, practice, delivery, effective use of voice and body language, effective use of audio visual aids, dos and don’ts of effective presentation

Public speaking-an art, language fluency, the domain expertise (Business GK, Current affairs), self-confidence, the audience, learning principles, body language, energy level and conviction, student presentations in teams of five with debriefing

Verbal

Vocabulary: Familiarize students with the etymology of words, help them realize the relevance of word analysis and enable them to answer synonym and antonym questions. Create an awareness about the frequently misspelt words, commonly confused words and wrong form of words in English.

Grammar: Train students to understand the nuances of English Grammar and thereby enable them to spot grammatical errors and punctuation errors in sentences.

Reasoning: Stress the importance of understanding the relationship between words through analogy questions and learn logical reasoning through syllogism questions. Emphasize the importance of avoiding the gap (assumption) in arguments/ statements/ communication.

Oral Communication Skills: Aid students in using the gift of the gab to improve their debating skills.

Writing Skills: Introduce formal written communication and keep the students informed about the etiquettes of email writing. Make students practise writing emails especially composing job application emails.

Aptitude

Numbers: Types, Power Cycles, Divisibility, Prime, Factors & Multiples, HCF & LCM, Surds, Indices, Square roots, Cube Roots and Simplification.

Percentage: Basics, Profit, Loss & Discount, and Simple & Compound Interest.

Ratio, Proportion & Variation: Basics, Alligations, Mixtures, and Partnership.

Averages: Basics, and Weighted Average.

Time and Work: Basics, Pipes & Cistern, and Work Equivalence.

Time, Speed and Distance: Basics, Average Speed, Relative Speed, Boats & Streams, Races and Circular tracks.

Statistics: Mean, Median, Mode, Range, Variance, Quartile Deviation and Standard Deviation.

Data Interpretation: Tables, Bar Diagrams, Line Graphs, Pie Charts, Caselets, Mixed Varieties, and other forms of data representation.

Equations: Basics, Linear, Quadratic, Equations of Higher Degree and Problems on ages.

Logarithms, Inequalities and Modulus: Basics

References

Soft Skills:

Communication and listening skills:

- Andrew J DuRbin , "Applied Psychology: Individual and organizational effectiveness", Pearson- Merril Prentice Hall, 2004
- Michael G Aamodt, "An Applied Approach, 6th edition", Wadsworth Cengage Learning, 2010

Assertiveness skills:

- Robert Bolton, Dorothy Grover Bolton, "People Style at Work..and Beyond: Making Bad Relationships Good and Good", Ridge Associates Inc., 2009
- John Hayes "Interpersonal skills at work", Routledge, 2003
- Nord, W. R., Brief, A. P., Atieh, J. M., & Doherty, E. M., "Meanings of occupational work: A collection of essays (pp. 21- 64)", Lexington, MA: Lexington Books, 1990

Self-perception and self-confidence:

- Mark J Martinko, "Attribution theory: an organizational perspective", St. Lucie, 1995
- Miles Hewstone, "Attribution Theory: Social and Functional Extensions", Blackwell, 1983

Time management:

- Stephen Covey, "The habits of highly effective people", Free press Revised edition, 2004
- Kenneth H Blanchard , "The 25 Best Time Management Tools & Techniques: How to Get More Done Without Driving Yourself Crazy" , Peak Performance Press, 1st edition 2005
- Kenneth H. Blanchard and Spencer Johnson, "The One Minute Manager" , William Morrow, 1984

Verbal:

- Erica Meltzer, "The Ultimate Guide to SAT Grammar"

- Green, Sharon, and Ira K. Wolf, “Barron's New GRE”, Barron's Educational Series, 2011
- Jeff Kolby, Scott Thornburg & Kathleen Pierce, “Nova’s GRE Prep Course”
- Kaplan, “Kaplan New GRE Premier”, 2011-2012
- Kaplan’s GRE Comprehensive Programme
- Lewis Norman, “Word Power Made Easy”, Goyal Publishers, Reprint edition, 1 June 2011
- Manhattan Prep, “GRE Verbal Strategies Effective Strategies Practice from 99th Percentile Instructors”
- Pearson- “A Complete Manual for CAT”, 2013
- R.S. Aggarwal, “A Modern Approach to Verbal Reasoning”
- S. Upendran, “Know Your English”, Universities Press (India) Limited, 2015
- Sharon Weiner Green, Ira K. Wolf, “Barron's New GRE, 19th edition (Barron's GRE)”, 2019
- Wren & Martin, “English Grammar & Composition”
- www.bbc.co.uk/learningenglish
- www.cambridgeenglish.org
- www.englishforeveryone.org
- www.merriam-webster.com

Aptitude:

- Arun Sharma, “How to Prepare for Quantitative Aptitude for the CAT Common Admission Test”, Tata Mc Graw Hills, 5th Edition , 2012
- Arun Sharma, “How to Prepare for Logical Reasoning for the CAT Common Admission Test”, Tata Mc Graw Hills, 2nd Edition, 2014
- Arun Sharma, “How to Prepare for Data Interpretation for the CAT Common Admission Test”, Tata Mc Graw Hills, 3nd Edition, 2015
- R.S. Aggarwal, “Quantitative Aptitude For Competitive Examinations”, S. Chand Publishing, 2015
- R.S. Aggarwal, “A Modern Approach To Verbal & Non-Verbal Reasoning”, S. Chand Publishing, Revised - 2015
- Sarvesh Verma, “Quantitative Aptitude-Quantum CAT”, Arihant Publications, 2016
- www.mbatious.com
- www.campusgate.co.in
- www.careerbless.com

Evaluation Pattern

Assessment	**Internal**	**External**
Continuous Assessment (CA)* – Soft Skills	30	-
Continuous Assessment (CA)* – Aptitude	10	25
Continuous Assessment (CA)* – Verbal	10	25
Total	50	50
Pass / Fail		

*CA - Can be **presentations, speaking activities and tests.**

23HU611	**Career Competency II**	**L-T-P-C: 0-0-3-1**

Pre-requisite: Willingness to learn, team spirit, basic English language and communication skills and knowledge of high school level arithmetic.

Course Objectives:

- Help students to understand the importance of interpersonal skills and team work
- Prepare the students for effective group discussions and interviews participation.
- Help students to sharpen their problem solving and reasoning skills

- Empower students to communicate effectively by using the correct diction, grammar and verbal reasoning skills

Course Outcomes:

CO1: Soft Skills - To demonstrate good interpersonal skills, solve problems and effectively participate in group discussions.

CO2: Soft Skills - To write technical resume and perform effectively in interviews.

CO3: Aptitude - To identify, investigate and arrive at appropriate strategies to solve questions on arithmetic by managing time effectively.

CO4: Aptitude - To investigate, understand and use appropriate techniques to solve questions on logical reasoning and data analysis by managing time effectively.

C05: Verbal - To be able to use diction that is more refined and appropriate and to be competent in knowledge of grammar to correct/improve sentences

C06: Verbal - To be able to examine, interpret and investigate passages and to be able to generate ideas, structure them logically and express them in a style that is comprehensible to the audience/recipient.

CO-PO Mapping

PO/CO	PO1	PO2	PO3
CO1	2	1	-
CO2	2	1	-
CO3	2	1	-
CO4	2	1	-
CO5	1	2	-
CO6	2	2	-

Syllabus

Soft Skills

Interpersonal skill: ability to manage conflict, flexibility, empathetic listening, assertiveness, stress management, problem solving, understanding one's own interpersonal needs, role of effective team work in organizations

Group problem solving: the process, the challenges, the skills and knowledge required for the same.

Conflict management: the concept, its impact and importance in personal and professional lives, (activity to identify personal style of conflict management, developing insights that helps in future conflict management situations.)

Team building and working effectively in teams: the concept of groups (teams), different stages of group formation, process of team building, group dynamics, characteristics of effective team, role of leadership in team effectiveness. (Exercise to demonstrate the process of emergence of leadership in a group, debrief and reflection), group discussions.

Interview skills: what is the purpose of a job interview, types of job interviews, how to prepare for an interview, dos and don'ts of interview, One on one mock interview sessions with each student

Verbal

Vocabulary: Help students understand the usage of words in different contexts. Stress the importance of using refined language through idioms and phrasal verbs.

Grammar: Enable students to identify poorly constructed sentences or incorrect sentences and improvise or correct them.

Reasoning: Facilitate the student to tap her/his reasoning skills through critical reasoning questions and logical ordering of sentences.

Reading Comprehension: Enlighten students on the different strategies involved in tackling reading comprehension questions.

Public Speaking Skills: Empower students to overcome glossophobia and speak effectively and confidently before an audience.

Writing Skills: Practice closet tests that assess basic knowledge and skills in usage and mechanics of writing such as punctuation, basic grammar and usage, sentence structure and rhetorical skills such as writing strategy, organization, and style.

Aptitude

Sequence and Series: Basics, AP, GP, HP, and Special Series.
Geometry: 2D, 3D, Coordinate Geometry, and Heights & Distance.
Permutations & Combinations: Basics, Fundamental Counting Principle, Circular Arrangements, and Derangements.
Probability: Basics, Addition & Multiplication Theorems, Conditional Probability and Bayes' Theorem.
Logical Reasoning I: Arrangements, Sequencing, Scheduling, Venn Diagram, Network Diagrams, Binary Logic, and Logical Connectives, Clocks, Calendars, Cubes, Non-Verbal reasoning and Symbol based reasoning.
Logical Reasoning II: Blood Relations, Direction Test, Syllogisms, Series, Odd man out, Coding & Decoding, Cryptarithmetic Problems and Input - Output Reasoning.
Data Sufficiency: Introduction, 5 Options Data Sufficiency and 4 Options Data Sufficiency.
Campus recruitment papers: Discussion of previous year question papers of all major recruiters of Amrita Vishwa Vidyapeetham.
Miscellaneous: Interview Puzzles, Calculation Techniques and Time Management Strategies.

References

Soft Skills

Team Building

- Thomas L.Quick, "Successful team building", AMACOM Div American Mgmt Assn, 1992
- **Brian Cole Miller, "Quick Team-Building Activities for Busy Managers: 50 Exercises That Get Results in Just 15 Minutes", AMACOM; 1 edition, 2003.**
- **Patrick Lencioni, "The Five Dysfunctions of a Team: A Leadership Fable", Jossey-Bass, 1st Edition, 2002**

Verbal

- "GMAT Official Guide" by the Graduate Management Admission Council, 2019
- Arun Sharma, "How to Prepare for Verbal Ability And Reading Comprehension For CAT"
- Joern Meissner, "Turbocharge Your GMAT Sentence Correction Study Guide", 2012
- Kaplan, "Kaplan GMAT 2012 & 13"
- Kaplan, "New GMAT Premier", Kaplan Publishing, U.K., 2013
- Manhattan Prep, "Critical Reasoning 6th Edition GMAT"
- Manhattan Prep, "Sentence Correction 6th Edition GMAT"
- Mike Barrett "SAT Prep Black Book The Most Effective SAT Strategies Ever Published"
- Mike Bryon, "Verbal Reasoning Test Workbook Unbeatable Practice for Verbal Ability, English Usage and Interpretation and Judgement Tests"
- www.bristol.ac.uk/arts/skills/grammar/grammar_tutorial/page_55.htm
- www.campusgate.co.in

Aptitude

- Arun Sharma, "How to Prepare for Quantitative Aptitude for the CAT Common Admission Test", Tata Mc Graw Hills, 5th Edition, 2012
- Arun Sharma, "How to Prepare for Logical Reasoning for the CAT Common Admission Test", Tata Mc Graw Hills, 2nd Edition , 2014
- Arun Sharma, "How to Prepare for Data Interpretation for the CAT Common Admission Test", Tata Mc Graw Hills, 3nd Edition , 2015
- R.S. Aggarwal, "Quantitative Aptitude For Competitive Examinations", S. Chand Publishing , 2015
- R.S. Aggarwal, "A Modern Approach To Verbal & Non-Verbal Reasoning", S. Chand Publishing , Revised - 2015
- Sarvesh Verma, "Quantitative Aptitude-Quantum CAT" , Arihant Publications , 2016
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Evaluation Pattern

Assessment	**Internal**	**External**
Continuous Assessment (CA)* – Soft Skills	30	-
Continuous Assessment (CA)* – Aptitude	10	25
Continuous Assessment (CA)* – Verbal	10	25
Total	50	50

*CA - Can be **presentations, speaking activities and tests.**