NEW HORIZON COLLEGE OF ENGINEERING

DEPARTMENT OF MECHANICAL ENGINEERING

Academic Year 2026–27

5th and 6th Semester
Scheme & Syllabus
BATCH: 2024–28
CREDITS: 160

NEW HORIZON COLLEGE OF ENGINEERING

VISION

To emerge as an institute of eminence in the fields of engineering, technology and management in serving the industry and the nation by empowering students with a high degree of technical, managerial and practical competence.

MISSION

- To strengthen the theoretical, practical and ethical dimensions of the learning process by fostering a culture of research and innovation among faculty members and students.
- To encourage long-term interaction between the academia and industry through their involvement in the design of curriculum and its hands-on implementation.
- To strengthen and mould students in professional, ethical, social and environmental dimensions by encouraging participation in co-curricular and extracurricular activities.

QUALITY POLICY

To provide educational services of the highest quality both curricular and co-curricular to enable students integrate skills and serve the industry and society equally well at global level

VALUES

- Academic Freedom
- Integrity
- Inclusiveness
- Innovation
- Professionalism
- Social Responsibility

DEPARTMENT OF MECHANICAL ENGINEERING

VISION

To create competent mechanical engineers capable of working in diversified disciplines for transformative impact on societal progressive development in the field of mechanical engineering through creative research and lifelong learning

MISSION

- To impart excellent education by providing the state of art research facilities in the field of mechanical engineering.
- To develop alliances with industries and other organizations for excellence in teaching learning process, research and consultancy projects.
- To enhance the knowledge of students in intellectual, entrepreneurial and ethical challenges through active participation by critical thinking.

PROGRAM EDUCATIONAL OBJECTIVES (PEOs)

- **PEO 1**: The graduates will be able to apply the overall knowledge of Mechanical Engineering along with concepts of Mathematics, Science, Communication and Computing skills to understand specific problem areas and finding the optimal solutions for the same.

- **PEO 2**: The graduates will be able to implement ideas of Mechanical Engineering for the challenging tasks in the interdisciplinary areas like Electrical, Electronics, Computer Science, Civil, Bio-Technology and allied branches.

- **PEO 3**: The graduates will be widely talented in the fields of manufacturing, service and design industries, which will not only improve their employability but also aid in establishing the above said industries.

- **PEO 4**: The graduates will develop lifelong learning attitudes, ethics and values that will help their career employability and growth in engineering, academia, defence, state and central government sectors.

PEO TO MISSION STATEMENT MAPPING

Program Educational Objectives	M1	M2	M3
PEO 1	3	2	3
PEO 2	2	3	2
PEO 3	2	3	2
PEO 4	1	2	3

KNOWLEDGE AND ATTITUDE PROFILE (WK)

WK1: A systematic, theory-based understanding of the natural sciences applicable to the discipline and awareness of relevant social sciences.

WK2: Conceptually-based mathematics, numerical analysis, data analysis, statistics and formal aspects of computer and information science to support detailed analysis and modelling applicable to the discipline.

WK3: A systematic, theory-based formulation of engineering fundamentals required in the engineering discipline.

WK4: Engineering specialist knowledge that provides theoretical frameworks and bodies of knowledge for the accepted practice areas in the engineering discipline; much is at the forefront of the discipline.

WK5: Knowledge, including efficient resource use, environmental impacts, whole-life cost, reuse of resources, net zero carbon, and similar concepts, that supports engineering design and operations in a practice area.

WK6: Knowledge of engineering practice (technology) in the practice areas in the engineering discipline.

WK7: Knowledge of the role of engineering in society and identified issues in engineering practice in the discipline, such as the professional responsibility of an engineer to public safety and sustainable development.

WK8: Engagement with selected knowledge in the current research literature of the discipline, awareness of the power of critical thinking and creative approaches to evaluate emerging issues.

WK9: Ethics, inclusive behavior and conduct. Knowledge of professional ethics, responsibilities, and norms of engineering practice. Awareness of the need for diversity by reason of ethnicity, gender, age, physical ability etc. with mutual understanding and respect, and of inclusive attitudes.

PROGRAM OUTCOMES (POs)

Graduate Attributes	PO #	Program Outcomes
Engineering knowledge	1	Apply knowledge of mathematics, natural science, computing, engineering fundamentals and an engineering specialization as specified in WK1 to WK4 respectively to develop to the solution of complex engineering problems.
Problem Analysis	2	Identify, formulate, review research literature and analyze complex engineering problems reaching substantiated conclusions with consideration for sustainable development. (WK1 to WK4)
Design Development of Solutions	3	Design creative solutions for complex engineering problems and design/develop systems/components/processes to meet identified needs with consideration for the public health and safety, whole-life cost, net zero carbon, culture, society and environment as required. (WK5)
Conduct Investigations of Complex Problems	4	Conduct investigations of complex engineering problems using research-based knowledge including design of experiments, modelling, analysis & interpretation of data to provide valid conclusions. (WK8).
Engineering Tool Usage	5	Create, select and apply appropriate techniques, resources and modern engineering & IT tools, including prediction and modelling recognizing their limitations to solve complex engineering problems. (WK2 and WK6)
The Engineer and The World	6	Analyze and evaluate societal and environmental aspects while solving complex engineering problems for its impact on sustainability with reference to economy, health, safety, legal framework, culture and environment. (WK1, WK5, and WK7).
Ethics	7	Apply ethical principles and commit to professional ethics, human values, diversity and inclusion; adhere to national & international laws. (WK9)
Individual and Collaborative Team work	8	Function effectively as an individual, and as a member or leader in diverse/multi-disciplinary teams
Communication	9	Communicate effectively and inclusively within the engineering community and society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations considering cultural, language, and learning differences
Project Management and Finance	10	Apply knowledge and understanding of engineering management principles and economic decision-making and apply these to one's own work, as a member and leader in a team, and to manage projects and in multidisciplinary environments.
Life-Long Learning	11	Recognize the need for, and have the preparation and ability for i) independent and life-long learning ii) adaptability to new and emerging technologies and iii) critical thinking in the broadest context of technological change. (WK8)

PROGRAM SPECIFIC OUTCOMES (PSOs)

After successful completion of mechanical Engineering Program, the graduates will be able to:

PSO1	Specify, fabricate, test and operate various machines along with essential documentations.
PSO2	Analyze, design, develop and implement the concepts of mechanical systems and processes towards product development

NEW HORIZON COLLEGE OF ENGINEERING
B. E. in Mechanical Engineering

V Semester													
S. No.	**Course and Course Code**		**Course Title**	**BoS**	**Credit Distribution**				**Overall Credits**	**Contact Hours**	**Marks**		
					L	**T**	**P**	**S**			**CIE**	**SEE**	**Total**
1	HSMS	24MEE51	Operations Research and Project Management	ME	3	0	0	0	3	3	50	50	**100**
2	PCC	24MEE52	Heat Transfer	ME	3	0	0	0	3	3	50	50	**100**
3	PCCL	24MEL52	Heat Transfer Lab	ME	0	0	1	0	1	2	50	50	**100**
4	PCC	24MEE53	Theory of Machines	ME	3	0	0	0	3	3	50	50	**100**
5	PCCL	24MEL53	Theory of Machines Lab	ME	0	0	1	0	1	2	50	50	**100**
6	AEC*	24MEE54	Drone Technology	ME	3	0	0	0	3	3	50	50	**100**
7	AEC	24RMK55	Research Methodology and IPR	ME	1	0	0	0	1	1	50	50	**100**
8	AEC	24SDK56	Problem Solving Methodologies	-	0	0	1	0	1	2	50	-	**50**
9	PROJ **	24MEE57	Societal Based Mini Project	ME	0	0	1	0	1	2	50	50	**100**
10	OEC*	26NHOP5XX	Industrial Open Elective Course-I	ME	3	0	0	0	3	3	50	50	**100**
11	NCMC	24NSS50	National Service Scheme	-	0	0	0	0	0	2	50	--	**50**
		24PED50	Physical Education and Sports	-									
		24YOG50	Yoga	-									
Total									**20**	**26**	**550**	**450**	**1000**

PCC: Professional Core Course, **PCCL**: Professional Core Course laboratory, **UHV**: Universal Human Value Course, **NCMC:** Non-Credit Mandatory Course, **AEC**: Ability Enhancement Course, **PEC**: Professional Elective Course, **PROJ**: Mini Project work **L:** Lecture, **T**: Tutorial, **P**: Practical **S: SDA**: Self Study for Skill Development, **CIE**: Continuous Internal Evaluation, **SEE**:Semester End Evaluation

AEC* (Skill Based Core Course):
Credit for AEC* with 03 (L: T: P: S) credits can be considered as (3: 0: 0: 0). The teaching and learning of these Courses will be based on hands-on. The Course content will be from Industry Certification Course Content. The Course Assessment will be based on CIE and SEE in practical mode.

Societal Based Mini Project **:

The Mini project can be done in any lab across college. A common slot in time table can be allotted across all departments.

Mini Project is a laboratory-oriented/hands on course that will provide a platform to students to enhance their practical knowledge and skills by the development of small systems/applications etc. Based on the ability/abilities of the student/s and recommendations of the mentor. A student can do mini project as

(i) A group of 2 if mini project work is single discipline (applicable to all IT allied branches)

(ii) A group of 3- 4 if mini project work is single discipline (applicable to all Core Branches)

(iii) A group of 3 - 4 students if the Mini Project work is a multidisciplinary (Applicable to all Branches)

CIE procedure for Mini-project:

(i) Single discipline: The CIE marks shall be awarded by a committee consisting of the Head of the concerned Department and two faculty members of the Department, one of them being the Guide. The CIE marks awarded for the Mini-project work shall be based on the evaluation of the project report, project presentation skill, and question and answer session in the ratio of 50:25:25. The marks awarded for the project report shall be the same for all the batches mates.

(ii) Interdisciplinary: Continuous Internal Evaluation shall be group-wise at the college level with the participation of all the guides of the project.

The CIE marks awarded for the Mini-project, shall be based on the evaluation of the project report, project presentation skill, and question and answer session in the percentage ratio of 50:25:25. The marks awarded for the project report shall be the same for all the batch mates.

Industrial Open Elective Courses-I:

Credit for OEC is 03 (L: T: P: S) can be considered as (3: 0: 0 : 0). The teaching and learning of these Courses will be based on hands-on. The Course Assessment will be based on CIE and SEE in practical mode. This Courses will be offered by Centre of Excellence to students of all the branches. Registration to Industrial open electives shall be documented and monitored on college level.

National Service Scheme /Physical Education/Yoga: All students have to register for any one of the courses namely National Service Scheme (NSS), Physical Education (PE) (Sports and Athletics), and Yoga (YOG) with the concerned coordinator of the course during the first week of III semesters. Activities shall be carried out between III semester to the VI semester (for 4 semesters). Successful completion of the registered course and requisite CIE score is mandatory for the award of the degree. The events shall be appropriately scheduled by the colleges and the same shall be reflected in the calendar prepared for the NSS, PE, and Yoga activities. These courses shall not be considered for vertical progression as well as for the calculation of SGPA and CGPA, but completion of the course is mandatory for the award of degree.

Credit Definition: 1-hour Lecture (L) per week=1Credit 2-hoursTutorial(T) per week=1Credit 2-hours Practical / Drawing (P) per week=1Credit 2-hous Self Study for Skill Development (SDA) per week = 1 Credit	03-Credits courses are to be designed for 40 hours in Teaching-Learning Session 02- Credits courses are to be designed for 25 hours of Teaching-Learning Session 01-Credit courses are to be designed for 15 hours of Teaching-Learning Sessions

NEW HORIZON COLLEGE OF ENGINEERING
B. E. in Mechanical Engineering

VI Semester													
S. No.	**Course and Course Code**		**Course Title**	**BoS**	**Credit Distribution**				**Overall Credits**	**Contact Hours**	**Marks**		
					L	**T**	**P**	**S**			**CIE**	**SEE**	**Total**
1	PCC	24MEE61	Robotics and Digital Twin Technology	ME	3	0	0	0	3	3	50	50	**100**
2	PCCL	24MEL61	Robotics and Digital Twin Lab	ME	0	0	1	0	1	2	50	50	**100**
3	PCC	24MEE62	Finite Element Methods	ME	3	0	0	0	3	3	50	50	**100**
4	PCCL	24MEL62	Finite Element Methods Lab	ME	0	0	1	0	1	2	50	50	**100**
5	AEC*	24MEK63	Computational Fluid Dynamics	ME	3	0	0	0	3	3	50	50	**100**
6	PEC	24MEE64X	Professional Elective Course-II	ME	3	0	0	0	3	3	50	50	**100**
7	AEC	24MEE65X	Ability Enhancement Course – V	ME	If the course is a Theory						50	50	**100**
					1	0	0	0	1	1			
					If the course is a laboratory								
					0	0	1	0	1	2			
8	NCMC	24SDK66	Advanced Problem Solving Methodologies	-	0	0	0	0	0	2	50	--	**50**
9	PROJ	24MEE67	Cap Stone Project	ME	0	0	2	0	2	4	50	50	**100**
10	PCC	26NHOP6XX	Industrial Open Elective Course-II	Offering Dept.	3	0	0	0	3	3	50	50	**100**
11	NCMC	24NSS60	National Service Scheme	-	0	0	0	0	0	2	50	--	**50**
		24PED60	Physical Education	-									
		24YOG60	Yoga	-									
								Total	**20**	**28/29**	**550**	**450**	**1000**

PCC: Professional Core Course, **PCCL**: Professional Core Course laboratory, **NCMC:** Non-Credit Mandatory Course, **AEC**: Ability Enhancement Course, **PEC**: Professional Elective Course, **OEC**: Open Elective Course, **PROJ**: Project work**, L:** Lecture, **T**: Tutorial, **P**: Practical **S: SDA**: Self Study for Skill Development, C**IE**: Continuous Internal Evaluation, **SEE**: Semester End Evaluation.

Professional Elective Course-II			
24MEE641	Reliability and Maintenance Engineering	24MEE644	Refrigeration and Air Conditioning
24MEE642	Fracture Mechanics	24MEE645	Non Traditional Machining
24MEE643	Digital Twin Technology		

Ability Enhancement Course – V			
24MEE651	Python Programming for Mechanical Applications	24MEE654	R Programming
24MEE652	Introduction to Augment and Virtual Reality	24MEE655	Deep Learning
24MEE653	Generative AI		

Industrial Open Elective Courses-II:
Credit for OEC is 03 (L: T: P: S) can be considered as (3: 0: 0 : 0). The teaching and learning of these Courses will be based on hands-on. The Course Assessment will be based on CIE and SEE in practical mode. This Courses will be offered by Centre of Excellence to students of all the branches. Registration to Industrial open electives shall be documented and monitored on college level.

Professional Elective Courses (PEC): A professional elective (PEC) course is intended to enhance the depth and breadth of educational experience in the Engineering and Technology curriculum. Multidisciplinary courses can be added to supplement the latest trend and advanced technology in the selected stream of engineering.

Cap Stone Project Phase-I:

Students have to discuss with the mentor /guide and with their help he/she has to complete the literature survey and prepare the report and finally define the problem statement for the project work.

The objective of the Project work is

- To encourage independent learning and the innovative attitude of the students.
- To develop interactive attitude, communication skills, organization, time management, and presentation skills.
- To impart flexibility and adaptability.
- To inspire team working.
- To expand intellectual capacity, credibility, judgment and intuition.
- To adhere to punctuality, setting and meeting deadlines.
- To install responsibilities to oneself and others.
- To train students to present the topic of project work in a seminar without any fear, face the audience confidently, enhance communication skills, involve in group discussion to present and exchange ideas.

CIE procedure for Project Work:

1. **Single discipline:** The CIE marks shall be awarded by a committee consisting of the Head of the concerned Department and two senior faculty members of the Department, one of whom shall be the Guide.
   The CIE marks awarded for the project work, shall be based on the evaluation of the project work Report, project presentation skill, and question and answer session in the percentage ratio of 50:25:25. The marks awarded for the project report shall be the same for all the batch mates.
2. **Interdisciplinary:** Continuous Internal Evaluation shall be group-wise at the college level with the participation of all guides of the college. Participation of external guide/s, if any, is desirable. The CIE marks awarded for the project work, shall be based on the evaluation of project work Report, project presentation skill, and question and answer session in the percentage ratio of 50:25:25. The marks awarded for the project report shall be the same for all the batch mates.

   SEE procedure for Project Work: SEE for project work will be conducted by the two examiners appointed by the University. The SEE marks awarded for the project work shall be based on the evaluation of project work Report, project presentation skill, and question and answer session in the percentage ratio of 50:25:25.

Credit Definition: 1-hour Lecture (L) per week=1Credit 2-hoursTutorial(T) per week=1Credit 2-hours Practical / Drawing (P) per week=1Credit 2-hous Self Study for Skill Development (SDA) per week = 1 Credit	03-Credits courses are to be designed for 40 hours in Teaching-Learning Session 02- Credits courses are to be designed for 25 hours of Teaching-Learning Session 01-Credit courses are to be designed for 15 hours of Teaching-Learning Sessions

V Semester Syllabus

OPERATIONS RESEARCH AND PROJECT MANAGEMENT

Course Code	**24MEE51**	**CIE Marks**	**50**
L:T:P:S	**3:0:0:0**	**SEE Marks**	**50**
Hrs / Week	**03**	**Total Marks**	**100**
Credits	**03**	**Exam Hours**	**03**

Course outcomes:

At the end of the course, the student will be able to:

24MEE51.1	Understand the principles of Operations Research and network analysis techniques such as CPM and PERT for project planning.
24MEE51.2	Analyze sequencing problems for single, two, three, and multiple machines to determine the optimal job sequence.
24MEE51.3	Evaluate job priorities, processing times, machine availability, and scheduling constraints to determine optimal job sequences
24MEE51.4	Identify the significance of Game Theory in competitive decision-making and formulate payoff matrices for different strategies.
24MEE51.5	Understand the fundamental concepts of projects, including characteristics, objectives, activities, milestones, resources, and constraints.
24MEE51.6	Apply project planning techniques to estimate resource requirements, project costs, and identify potential risks

Mapping of Course Outcomes to Program Outcomes and Program Specific Outcomes:

	PO1	PO 2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2
24MEE51.1	3	3	2	-	-	-	-	-	-	-	-	2	2
24MEE51.2	3	3	3	-	-	-	-	-	-	-	-	2	2
24MEE51.3	3	3	3	1	-	-	-	-	-	-	-	2	2
24MEE51.4	3	3	3	-	-	-	-	-	-	-	-	2	2
24MEE51.5	2	2	-	-	-	2	-	-	1	3	2	-	2
24MEE51.6	3	2	-	-	-	2	-	-	1	3	2	-	2

MODULE-1	**BASICS OF OPERATION RESEARCH**	**24MEE51.1**	**8 Hours**

Introduction: Evolution, Definitions, Scope, Applications Phases, Characteristics and limitations of operation research. Network analysis: Introduction, Construction of networks, Fulkerson's rule for numbering the nodes, AON and AOA diagrams; Critical path method to find the expected completion time of a project, determination of floats in networks, PERT networks, determining the probability of completing a project, predicting the completion time of project.

Applications	PERT- CPM Technology for manufacturing plant
Text Book	Text Book 1: 1.1, 1.1, 1.8, 1.9, 1.10, 1.18, 1.16.

MODULE-2	**SEQUENCING**	**24MEE51.2 24MEE51.3**	**8 Hours**

Sequencing: Basic assumptions, Johnson's algorithm, sequencing 'n' jobs on single machine using priority rules, sequencing using Johnson's rule-'n' jobs on 2 machines, 'n' jobs on 3 machines, 'n' jobs on 'm' machines. Sequencing of 2 jobs on 'm' machines using graphical method.

Case Study	Sequencing for optimizing manufacturing company
Text Book	Text Book 1: 2.2, 2.3, 2.4 to 2.15

MODULE-3	GAMETHEORY	24MEE51.4	8 Hours

Game Theory: Definition, Pure Strategy problems, Saddle point, Maxi-Min and Mini-Max criteria, Principle of Dominance, Solution of games with Saddle point. Mixed Strategy problems. Solution of 2x2 games by Arithmetic method, Solution of 2xn, mx2 and mxn games by graphical method. Formulation of games.

Case Study	Game theory for business development strategy
Text Book	Text Book 2: 2.1 to 2.10

MODULE-4	INTRODUCTION TO PROJECT MANAGEMENT	24MEE51.5	8 Hours

Introduction: Definition of project, characteristics of projects, understand projects, types of projects, scalability of project tools, project roles Project Selection and Prioritization – Strategic planning process, Strategic analysis, strategic objectives, portfolio alignment – identifying potential projects, methods of selecting projects, financial mode / scoring models to select projects, prioritizing projects, securing and negotiating projects.

Case Study	Create project management plan for inventory planning
Text Book	Text Book 3 : Chapter 11.1, 11.2, 11.3

MODULE-5	PROJECT PLANNING AND CONTROL FUNDAMENTALS	24MEE51.6	8 Hours

Resourcing Projects: Abilities needed when resourcing projects, estimate resource needs, creating staffing management plant, project team composition issues, Budgeting Projects: Cost planning, cost estimating, cost budgeting, establishing cost control. Project Risk Planning: Risk Management Planning, risk identification, risk analysis, risk response planning, Project Quality Planning and Project Kick off: Development of quality concepts, project quality management plan, project quality tools, kick off project, baseline and communicate project management plan, using Microsoft Project for project baselines.

Case Study	Develop a complete project plan for product development
Text Book	Text Book 3: Chapter 14.2, 14.3,14.6

CIE Assessment Pattern (50 Marks – Theory) –

RBT Levels		Marks Distribution		
		Test (s)	AAT1	AAT2
		25	15	10
L1	Remember	5	-	-
L2	Understand	5	5	-
L3	Apply	10	5	5
L4	Analyze	5	5	5
L5	Evaluate	-	-	-
L6	Create	-	-	-

SEE Assessment Pattern (50 Marks – Theory)

RBT Levels		Exam Marks Distribution (50)
L1	Remember	10
L2	Understand	10
L3	Apply	20
L4	Analyze	10
L5	Evaluate	--
L6	Create	--

Suggested Learning Resources:

Text Books:

1. Contemporary Project Management, Timothy J Kloppenborg, Cengage Learning, 2 nd Edition,2020, ISBN: 97881315187
2. Operations Research: An Introduction, H A Taha,Pearson; 10th edition ,2017, ISBN-13: 978-1292165547,2021
3. Engineering Economy, Thuesen H.G. PHI , 2020, ISBN-13: 978-0-07-337630-1

Reference Books

1. Engineering Economy, Riggs J.L., 4 TH ed. , McGraw Hill, 2022, ISBN:978-0070586703
2. Project Management a System approach to Planning Scheduling & Controlling, Harold Kerzner, CBS Publishers and Distributors.2nd Ed., 2022, ISBN: 9788123908670

Web links and Video Lectures (e-Resources):

- **https://www.youtube.com/watch?v=rBSCvPYGnTc**
- **https://www.youtube.com/watch?v=DiFTdX6-7ks**
- **https://www.youtube.com/watch?v=84Ejjd9YP8I&list=PLSGws_74K018S9XgERU9IA-M0z1l8XcFs**
- **https://www.youtube.com/watch?v=c6CpNqdJWDw**
- **https://www.youtube.com/watch?v=ky08C8uoPok**

Activity-Based Learning (Suggested Activities in Class)/ Practical Based learning

- Visit to any manufacturing/aero/auto industry/ R&D Center
- Demonstration of project management by taking any real time examples
- Demonstration of implementation of game theory in industries.
- Demonstration of application of sequencing in the industries
- For active participation of students, instruct the students to prepare Flowcharts and Handouts
- Organizing Group wise discussions on issues

HEAT TRANSFER

Course Code	**24MEE52**	**CIE Marks**	**50**
L:T:P:S	**3:0:0:0**	**SEE Marks**	**50**
Hrs / Week	**03**	**Total Marks**	**100**
Credits	**03**	**Exam Hours**	**03**

Course outcomes:

At the end of the course, the student will be able to:

24MEE52.1	Understand the fundamental concepts, governing laws, and boundary conditions of conduction, convection, and radiation heat transfer.
24MEE52.2	Apply the principles of one-dimensional steady and transient conduction, including lumped system analysis and Heisler's charts, to solve practical heat transfer problems
24MEE52.3	Analyze free and forced convection heat transfer using dimensional analysis and empirical correlations for different geometries and flow conditions.
24MEE52.4	Apply the principles of radiation heat transfer, including black body, gray body assumptions, and radiation shield concepts, to engineering applications
24MEE52.5	Design and assess heat exchangers using LMTD and Effectiveness-NTU methods by considering overall heat transfer coefficient, fouling, and temperature profiles
24MEE52.6	Develop innovative solutions for advanced thermal systems by exploring applications of micro, nano, and PCB type heat exchangers in modern engineering practice.

Mapping of Course Outcomes to Program Outcomes and Program Specific Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2
24MEE52.1	3	2	-	-	-	-	-	-	-	-	-	-	2
24MEE52.2	3	3	2	-	1	-	-	-	-	-	-	-	2
24MEE52.3	3	3	2	1	-	-	-	-	-	-	-	-	2
24MEE52.4	3	2	-	-	-	-	-	-	-	-	-	-	2
24MEE52.5	3	3	2	2	-	-	-	-	-	-	-	-	2
24MEE52.6	3	3	3	-	2	-	-	-	-	-	-	-	2

MODULE-1	**INTRODUCTION TO HEAT TRANSFER CONCEPTS**	**24MEE52.1**	**8 Hours**

Introduction to Concepts and Definitions: Modes of heat transfer; Basic laws governing conduction, convection, and radiation heat transfer; Boundary conditions of 1st, 2nd and 3rd kind (Numerical Problems). Derivation of general three-dimensional conduction equation in Cartesian coordinate and its special cases, discussion on 3-D conduction in cylindrical and spherical coordinate systems (No derivation). One dimensional conduction equation in rectangular, cylindrical and spherical coordinates for plane and composite walls (No Derivations only Numerical Problems). Thermal contact resistance (Numerical Problems).

Applications	Investigate the Practical Applications of Laws of Heat Transfer.
Text Book	Text Book 1: 1.1, 1.2, 1.3, 1.4,2.1,2.2,2.5,2.6 Text Book 2: 1.1, 1.2, 2.1,2.2,

MODULE-2	**TRANSIENT CONDUCTION**	**24MEE52.2**	**8 Hours**

Transient Conduction: Lumped system analysis, Use of Transient temperature charts (Heisler's charts) for transient conduction in slab, long cylinder and sphere; use of transient temperature charts for transient conduction in semi- infinite solids. Numerical Problems.

Case Study	Case study on Analysis of Transient Heat conduction in different Geometries.
Text Book	Text Book 1: 2.10,2.10.1,2.10.2,4.2,4.5Text Book 2: 1.1, 1.2, 1.3

MODULE-3	**FREE CONVECTIONS AND FORCED CONVECTIONS**	**24MEE52.3**	**8 Hours**

Free or Natural convection: Application of dimensional analysis for free convection, use of correlations of free convection in vertical, horizontal and inclined flat plates, vertical and horizontal cylinders and spheres, Numerical problems.
Forced Convections: Applications of dimensional analysis for forced convection, Use of various correlations for hydrodynamically and thermally developed, flows inside a duct, use of correlations for flow over a flat plate, over a cylinder and sphere. Numerical problems

Applications	Investigate the Application of dimensional analysis for free convection and forced convection.
Text Book	Text Book 1: 6.6, 7.1, 7.2 , 7.3 ,8.1,8.5,8.8 Text Book 2: 2.1, 2.3, 2.4, 2.5, 2.6

MODULE-4	**RADIATION HEAT TRANSFER**	**24MEE52.4**	**8 Hours**

Radiation Heat Transfer: Thermal radiation; definitions of various terms used in radiation heat transfer. Basic Laws: Stefan-Boltzmann law, Kirchoff's law, Planck's law and Wein's displacement law, Lambert's law. Radiation heat exchange between two parallel infinite black surfaces, between two parallel infinite gray surfaces; effect of radiation shield; intensity of radiation and solid angle; Numerical problems

Case Study	Case study on radiation heat transfer in Furnaces
Text Book	Text Book 1: 11.1,11.2,11.3,11.4,11.5,11.6,11.7,11.8,11.9 Text Book 2: 5.1, 5.3, 5.5, 5.7

MODULE-5	**HEAT EXCHANGERS**	**24MEE52.5 24MEE52.6**	**8 Hours**

Heat Exchangers: Classification of heat exchangers; Temperature profiles of Heat exchangers. Overall heat transfer coefficient, fouling and fouling factor; LMTD, Effectiveness-NTU methods of analysis of heat exchangers. Numerical problems. Introduction to the concepts of Micro, Nano and PCB type heat exchangers. AI-Based Thermal Management in Micro and Nano Heat Exchangers, Use of **Artificial Intelligence** for real-time monitoring of fouling and performance degradation in heat exchangers.

Case Study	Case study on Design of Heat Exchangers
Text Book	Text Book 1: 10.1,10.2,10.310.4,10.5, 9.1,9.2,9.3 Text Book 2: 8.1, 8.3, 8.4, 8.5, 8.6

CIE Assessment Pattern (50 Marks – Theory)

RBT Levels		Marks Distribution		
		Test (s)	AAT1	AAT2
		25	15	10
L1	Remember	5	-	-
L2	Understand	5	5	-
L3	Apply	10	5	5
L4	Analyze	5	5	5
L5	Evaluate	-	-	-
L6	Create	-	-	-

SEE Assessment Pattern (50 Marks – Theory)

RBT Levels		Exam Marks Distribution (50)
L1	Remember	10
L2	Understand	10
L3	Apply	20
L4	Analyze	10
L5	Evaluate	--
L6	Create	--

Suggested Learning Resources:

Text Books:

1. Heat & Mass transfer, R.K Rajaput, S Chand and Co Ltd, 7th Ed, 2025. ISBN:9789352837212
2. Engineering Heat and Mass transfer, Mahesh M. Rathore, Lakshmi Publication Pvt Ltd 3rd Edition, 2025, ISBN: 978-8131806135

Reference Books:

1. Heat transfer, a practical approach, Yunus A- Cengel Tata McGraw Hill,6th Ed, 2020, ISBN: 9789339223199
2. Principles of heat transfer, Kreith Thomas Learning ,7th Ed, 2017, ISBN-13: 978-0495657704
3. Fundamentals of heat and mass transfer, Frank P. Incropera and David P. Dewitt, John Wiley and sons, 7th Ed, 2018, ISBN-13: 9781118989173

Web links and Video Lectures (e-Resources):

- **https://onlinecourses.nptel.ac.in/noc20_ch21/preview**
- **https://www.youtube.com/watch?v=lvyCe0UaqJY**
- **https://www.udemy.com/course/fundamentals-of-heat-masstransfer-basic-to-advance-level/**
- **https://www.classcentral.com/course/swayam-heat-transfer-10061**

Activity-Based Learning (Suggested Activities in Class)/ Practical Based learning

- Visit to any Thermal power plant
- Demonstration of working of IC engine/refrigerator
- Video demonstration on Conduction, convection and radiation heat transfer
- Contents related activities (Activity-based discussions)
  - For active participation of students, instruct the students to prepare heat transfer related Flowcharts and Handouts
  - Organizing Group wise discussions on issues
  - Seminars

HEAT TRANSFER LAB

Course Code	**24MEL52**	**CIE Marks**	**50**
L:T:P:S	**0:0:1:0**	**SEE Marks**	**50**
Hrs / Week	**02**	**Total Marks**	**100**
Credits	**01**	**Exam Hours**	**03**

Course outcomes:

At the end of the course, the student will be able to:

24MEL52.1	Apply the concept of steady-state heat conduction using analytical and numerical methods to determine temperature distribution and heat flux in rods and composite walls.
24MEL52.2	Formulate one-dimensional conduction equations for systems such as fins and lumped bodies, and develop appropriate solutions for temperature distribution.
24MEL52.3	Analyze the concept of blackbody radiation to evaluate emissivity and radiative characteristics of surfaces.
24MEL52.4	Analyze free and forced convection, boiling, and condensation heat transfer in ducts and vertical surfaces using dimensional analysis, empirical correlations, and engineering principles.

Mapping of Course Outcomes to Program Outcomes and Program Specific Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2
24MEL52.1	3	3	1	-	-	-	-	-	-	-	-	3	2
24MEL52.2	3	2	2	-	-	-	-	-	-	-	-	3	2
24MEL52.3	3	2	2	-	-	-	-	-	-	-	-	3	2
24MEL52.4	3	2	2	-	-	-	-	-	-	-	-	3	2

Exp. No.	List of Experiments	Hours	COs
	Prerequisite Experiments / Demo		
	• Conduction, convection and radiation concepts and Laws • Engineering Thermodynamics concepts and Laws • Thermal analysis using FEM	2	NA
	PART-A		
1	Determination of Thermal Conductivity of a Metal Rod.	2	24MEL52.1
2	Determination of Overall Heat Transfer Coefficient of a Composite wall.	2	24MEL52.1
3	Analysis of Composite walls using FEM Techniques	2	24MEL52.1
4	Determination of Temperature Distribution during Transient Heat Conduction	2	24MEL52.2
5	Determination of Emissivity of a Surface	2	24MEL52.3
6	Determination of Heat Transfer Coefficient in a free Convection on a vertical/horizontal tube	2	24MEL52.4
	PART-B		
7	Determination of Heat Transfer Coefficient in a Forced Convention on a vertical/horizontal tube.	2	24MEL52.4
8	Determination of Heat transfer co-efficient, efficiency & Effectiveness on a Metallic fin by Free convection	2	24MEL52.4
9	Determination of Heat transfer co-efficient, efficiency & Effectiveness on a Metallic fin by forced convection	2	24MEL52.4

10	Determination of heat transfer coefficient in film wise condensation.	2	24MEL52.4
11	Determination of heat transfer coefficient in drop wise condensation.	2	24MEL52.4
12	Demonstration on LMTD of Parallel flow and Counter flow Heat exchangers	2	24MEL52.4

PART-C
Beyond Syllabus Virtual Lab Content

- **Thermal conductivity of a metal rod**
  https://sites.google.com/view/vlab-bnmitmech/home/heat-transfer-lab/natural-convection?authuser=0
- **Natural Convection**
  https://vlab.amrita.edu/index.php?sub=1&brch=194&sim=791&cnt=1
- **Heat Transfer by Radiation**
  https://vlab.amrita.edu/index.php?sub=1&brch=194&sim=802&cnt=1

CIE Assessment Pattern (50 Marks – Lab)

RBT Levels		Test (s)	Weekly Assessment
		20	30
L1	Remember	-	-
L2	Understand	-	10
L3	Apply	10	10
L4	Analyze	10	10
L5	Evaluate	-	-
L6	Create	-	-

SEE Assessment Pattern (50 Marks – Lab)

RBT Levels		Exam Marks Distribution (50)
L1	Remember	05
L2	Understand	05
L3	Apply	20
L4	Analyze	20
L5	Evaluate	-
L6	Create	-

Suggested Learning Resources:

Reference Books:

1. Heat transfer, a practical approach, Yunus A- Cengel Tata McGraw Hill,6th Ed, 2020, ISBN: 9789339223199
2. Principles of heat transfer, Kreith Thomas Learning ,7th Ed, 2017, ISBN-13: 978-0495657704
3. Fundamentals of heat and mass transfer, Frank P. Incropera and David P. Dewitt, John Wiley and sons, 7th Ed, 2018, ISBN-13: 9781118989173

THEORY OF MACHINES

Course Code	**24MEE53**	**CIE Marks**	**50**
L:T:P:S	**3:0:0:0**	**SEE Marks**	**50**
Hrs / Week	**3**	**Total Marks**	**100**
Credits	**03**	**Exam Hours**	**03**

Course outcomes:

At the end of the course, the student will be able to:

24MEE53.1	Apply the principles of kinematics to analyze planar mechanisms by determining mobility, studying mechanism inversions, evaluating special-purpose mechanisms,
24MEE53.2	Design the velocity and acceleration characteristics of four-bar and single slider-crank mechanisms for kinematic performance evaluation..
24MEE53.3	Determine the governing and balancing parameters of governors and flywheels to enhance the performance of mechanical systems through analytical and numerical methods.
24MEE53.4	Analyze balancing requirements of rotating and reciprocating masses to minimize vibrations in mechanical systems.
24MEE53.5	Investigate the precessional motion and gyroscopic effects of rotating bodies to evaluate their influence on the stability and maneuverability of engineering systems.
24MEE53.6	Design gear transmission systems by applying gearing principles and AI-based optimization methods.

Mapping of Course Outcomes to Program Outcomes and Program Specific Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2
24MEE53.1	3	3	2	-	-	-	-	-	-	-	-	-	3
24MEE53.2	3	3	2	-	2	-	-	-	-	-	-	-	3
24MEE53.3	3	3	2	-	2	-	-	-	-	-	-	-	3
24MEE53.4	3	3	2	-	2	-	-	-	-	-	-	-	3
24MEE53.5	3	3	2	-	2	-	-	-	-	-	-	-	3
24MEE53.6	3	2	3	2	3	-	-	-	-	-	-	-	3

MODULE-1	**INTRODUCTION AND MECHANISMS**	**24MEE53.1 24MEE53.2**	**8 Hours**

Introduction and Mechanisms: Definitions of Link, kinematic pairs, kinematic chain, mechanism, structure, degrees of freedom, Classification of pairs. Grashoff's Law, Grubler's Criterion, Inversions of four bar chain, single slider chain and double slider chain. Straight line mechanism- Peaucellier's mechanism, Intermittent mechanism- Geneva wheel mechanism, toggles mechanism. Ackerman steering gear mechanism. Velocity and Acceleration Analysis of Mechanisms of four bar and single slider crank mechanism (Analytical Method).

Case study	Different mechanism and applications of it by building the models.
Text Book	Text Book 1: 9.1 to 9.16

MODULE-2	**GOVERNORS AND FLYWHEEL**	**24MEE53.3**	**8 Hours**

Governors and flywheel: Introduction, types of governors, Centrifugal Governor, Watt Governor, Porter and Hartnell governor Stability, Sensitivity, lift, Isochronous, Hunting, power& effort, and coefficient of insensitiveness Controlling force, Flywheel, Numericals

Self study	Demonstration of various Governors in the Laboratory
Text Book	Text Book 1: 18.1-18.6.18.10,18.17

MODULE-3	**BALANCING OF ROTATING AND RECIPROCATING MASSES**	**24MEE53.4**	**8 Hours**

Balancing of rotating masses: Static and Dynamic Balancing, Balancing of single rotating mass in a single plane. Balancing of several rotating mass in single plane and multiple planes. Numericals, Balancing of Reciprocating masses(only Theory)

Application	Demonstration of various rotating masses in same and different planes in the laboratory

Text Book	Text Book 1: 21.1-21.6		
MODULE-4	**GYROSCOPE**	**24MEE53.5**	**8 Hours**
Introduction, Basic defnitions, Precessional angular motion, gyroscopic couple, Gyroscopic effect of a disc, ship, aero plane, two wheelers and four wheelers with vector diagrams, Numericals			
Case study	Demonstration of Gyroscopic effect in the laboratory		
Text Book	Text Book 1:14.1-14.9 Text Book 2: 10.1, 10.3, 10.5, 10.7		
MODULE-5	**SPUR GEARS and GEAR TRAINS**	**24MEE53.6**	**8 Hours**
Gear Terminology, Law of Gearing, Length of arc of contact, Minimum number of teeth on a gear to avoid interference and Minimum number of teeth on a pinion to avoid Interference ,Numericals Gear Trains: Simple,Compound gear trainsfor speed reduction, Epicyclic gear trains ,Algebraic and Tabular methods for finding velocity ratio, Torque calculations. **AI based gear design optimization**			
Applications	Practical applications of Different gears in an Automobile		
Textbook	Text Book 2: 12.1 to 12.10		

CIE Assessment Pattern (50 Marks – Theory) –

RBT Levels		Marks Distribution		
		Test (s)	AAT1	AAT2
		25	15	10
L1	Remember	5	-	-
L2	Understand	5	5	-
L3	Apply	10	5	5
L4	Analyze	5	5	5
L5	Evaluate	-	-	-
L6	Create	-	-	-

SEE Assessment Pattern (50 Marks – Theory)

RBT Levels		Exam Marks Distribution (50)
L1	Remember	10
L2	Understand	10
L3	Apply	20
L4	Analyze	10
L5	Evaluate	--
L6	Create	--

Suggested Learning Resources:

Text Books:

1) Theory of machines by RS Khurmi and JK Gupta S Chand Publishers, 14th Ed, 2022, ISBN: 9788121925372

2) Mechanism and Machine Theory by Ambekar A G, Prentice Hall India Learning Private Limited, 2024, ISBN : 978-81-203-3134-1

Reference Books:

1)Theory of machines by Ballaney, Khanna Publishers, 25th Ed, 2024, ISBN-13: 9788174091222

2) Theory of machines by Sadhu Singh, Pearson Education India, 2006, ISBN,87581279.

3) Theory of machines by S.S. Rattan Tata McGraw Hill Publications,5th Ed,2019, ISBN:9789351343479

4) Kinematics of machines by Srinath M.K., Skyward publishers, 2020, ISBN-978-93-86442-00-01

Web links and Video Lectures (e-Resources):

- **https://www.youtube.com/watch?v=EVqBzOGQlkI**
- **https://www.youtube.com/watch?v=GF5C8dH4f5o**
- **https://www.youtube.com/watch?v=0MeAZFFqmek&list=PLdLe0dTcWWu_dCcNGoAK8fx2PiS5gkVu**
- **https://www.youtube.com/watch?v=GK0MTY4c3eE**

Activity-Based Learning (Suggested Activities in Class)/ Practical Based learning

- Visit to any Design company/aero/auto industry or any power plant
- .Demonstration of various Mechanisms
- Demonstration of working of Gyroscope.

THEORY OF MACHINES LAB

Course Code	**24MEL53**	**CIE Marks**	**50**
L:T:P:S	**0:0:1:0**	**SEE Marks**	**50**
Hrs / Week	**02**	**Total Marks**	**100**
Credits	**01**	**Exam Hours**	**03**

Course outcomes:

At the end of the course, the student will be able to:

24MEL53.1	Understand the concepts of natural frequency, logarithmic decrement, damping and damping ratio
24MEL53.2	Analyze the concept of the critical speed of a rotating shaft.
24MEL53.3	Analyze the inversions of mechanisms for different motion transfer scenarios
24MEL53.4	Apply the solutions for Unbalance in rotary components of different machines and parameters which affect the performance of Governors

Mapping of Course Outcomes to Program Outcomes and Program Specific Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2
24MEL53.1	3	2	1	-	2	-	-	-	-	-	-	3	1
24MEL53.2	3	3	2	2	3	-	-	-	-	-	-	3	1
24MEL53.3	2	2	1	-	-	-	-	-	-	-	-	3	1
24MEL53.4	3	3	2	2	-	-	-	-	-	-	-	3	1

Exp. No	List of Experiments	Hours	COs
	Prerequisite Experiments		
	• Degrees of freedom, Forces, moments, equilibrium, and free-body diagrams. • Natural frequencies of different vibrating systems	2	NA
	PART-A		
1	Determination of natural frequency of simple pendulum	2	24MEL53.1
2	Determination of natural frequency of compound pendulum	2	24MEL53.1
3	Determination of natural frequency, logarithmic decrement, damping ratio and damping coefficient in a single degree of freedom of torsional vibrating systems	2	24MEL53.1
4	Determination of logarithmic decrement, damping ratio, damping frequency and natural frequency of a cantilever beam under free vibration	2	24MEL53.1
5	Determination of critical speed of a rotating shaft	2	24MEL53.2
6	Determine the logarithmic decrement, damping ratio, damping frequency and natural frequency of a fixed beam under free vibration	2	24MEL53.1
	PART-B		
7	Synthesis and simulation of 4 bar mechanism using multi-body dynamics software	2	24MEL33.3
8	Synthesis and simulation of Slider crank Chain using multibody dynamics software	2	24MEL33.3
9	Synthesis and simulation of Coupling rod of locomotive using multi-body dynamics software	2	24MEL33.4
10	Balancing of rotating masses in same plane using graphical Method in Solid edge.	2	24MEL33.4

11	Balancing of rotating masses in different planes using graphical method in solid edge	2	24MEL33.4
12	Determination of Sensitiveness and Controlling force of a Porter Governor	2	24MEL33.4

PART-C

Beyond Syllabus Virtual Lab Content

(To be done during Lab but not to be included for CIE or SEE)

- **Rotating-unbalance**
  https://mdmv-nitk.vlabs.ac.in/exp/exp-rotating-unbalance-nitk/
- **Simply-supported-beam**
  https://mdmv-nitk.vlabs.ac.in/exp/exp-simply-supported-beam-nitk/
- **Forced Vibration**
  https://mdmv-nitk.vlabs.ac.in/exp/exp-forced-vibration-nitk/videos.html
- **Velocity Acceleration analysis**
  https://mm-nitk.vlabs.ac.in/exp/acceleration-analysis-slider-crank/videos.html

CIE Assessment Pattern (50 Marks – Lab)

RBT Levels		Test (s)	Weekly Assessment
		20	30
L1	Remember	-	-
L2	Understand	-	10
L3	Apply	10	10
L4	Analyze	10	10
L5	Evaluate	-	-
L6	Create	-	-

SEE Assessment Pattern (50 Marks – Lab)

RBT Levels		Exam Marks Distribution (50)
L1	Remember	05
L2	Understand	05
L3	Apply	20
L4	Analyze	20
L5	Evaluate	-
L6	Create	-

Suggested Learning Resources:

REFERENCE BOOKS:

1) Theory of machines by Ballaney, Khanna Publishers, 25th Ed, 2024, ISBN-13: 9788174091222
2) Theory of machines by Sadhu Singh, Pearson Education India, 2006, ISBN,87581279.
3) Theory of machines by S.S. Rattan Tata McGraw Hill Publications,5th Ed,2019, ISBN:9789351343479
4) Kinematics of machines by Srinath M.K., Skyward publishers, 2020, ISBN-978-93-86442-00-01

DRONE TECHNOLOGY

Course Code	**24MEE54**	**CIE Marks**	**50**
L:T:P:S	**3:0:0:0**	**SEE Marks**	**50**
Hrs / Week	**3**	**Total Marks**	**100**
Credits	**03**	**Exam Hours**	**03**

Course outcomes:

At the end of the course, the student will be able to:

24MEE54.1	Understand UAV classifications, subsystem architectures, and safety protocols relevant to drone systems.
24MEE54.2	Apply CAD tools and additive manufacturing techniques to design and fabricate drone structural components, and determine GTOW and CG.
24MEE54.3	Analyze propulsion system parameters (KV rating, PWM) and characterize ESC-motor response characteristics.
24MEE54.4	Examine embedded platforms, sensor systems (IMU, GPS), and wireless communication protocols used in drone systems.
24MEE54.5	Analyze aerodynamic performance, energy systems, and apply AI-based techniques for autonomous drone operation and mission planning.
24MEE54.6	Apply pre-flight operational protocols, and demonstrate awareness of drone applications in professional domains including agriculture, surveillance, disaster management, and delivery systems.

Mapping of Course Outcomes to Program Outcomes and Program Specific Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2
24MEE54.1	2	1	-	1	2	1	2	-	-	-	1	1	1
24MEE54.2	2	2	3	2	3	-	-	1	1	1	1	3	3
24MEE54.3	2	3	2	3	3	-	-	1	-	-	1	2	3
24MEE54.4	2	2	2	2	3	-	-	1	1	-	1	1	2
24MEE54.5	2	3	3	3	3	1	1	1	1	1	2	2	3
24MEE54.6	1	2	1	1	1	3	3	-	1	1	2	1	1

MODULE-1	**INTRODUCTION TO UAV SYSTEMS AND REGULATIONS**	**24MEE54.1**	**8 Hours**

UAV Fundamentals - Classification of UAVs (multi-rotor, fixed-wing, hybrid VTOL, ornithopter); applications of UAVs in agriculture, surveillance, logistics, inspection, and defence.

System Architecture - Mechanical, propulsion, power, control, communication and payload subsystems; signal flow from transmitter to propeller; UAV system block diagram and integration concepts.

Hands on:

1. Taxonomy and Architectural Analysis: A Comprehensive Study of UAV Configurations and Subsystem Components

Case Study	Identify a suitable UAV configuration for aerial photography and briefly justify the choice based on its application and basic system components

MODULE-2	**STRUCTURAL DESIGN AND FABRICATION**	**24MEE54.2**	**8 Hours**

CAD Modelling - Design principles of drone components; symmetry, stability and weight considerations; modelling of drone frames, motor mounts, landing gear, sensor housings and payload brackets using Fusion 360.

Mass Properties and Simulation - Gross Take-Off Weight (GTOW); Centre of Gravity (CG) determination using principle of moments; effect of component placement on stability; CAD-based mass property simulation and comparison with analytical calculations.

Additive Manufacturing: FDM printing process; STL generation and slicing workflow; materials for drone fabrication (PLA, PETG, PETG-CF, SLS); dimensional inspection and structural assessment of printed components.

Hands on:

1. Computer-Aided Design and Modelling of Drone Components using SolidWorks / AutoCAD
2. Additive Manufacturing: 3D Printing and Rapid Prototyping of Drone Components
3. Simulation and Mass Properties Analysis for Determining GTOW and Centre of Gravity (CG)

Self-study	Compare PLA, PETG, and PETG-CF as drone frame materials and evaluate each on weight, tensile strength, print difficulty, and cost. Present findings as a material selection matrix.

MODULE-3	**PROPULSION AND ELECTRONIC CONTROL SYSTEMS**	**24MEE54.3**	**8 Hours**

BLDC Motors - Outrunner vs inrunner classification; KV rating and RPM-voltage relationship; Motor selection criteria for drone applications; Speed measurement using tachometer at varying voltages.
ESC and PWM Control - ESC architecture and operation; electronic commutation; PWM control signals; throttle-to-speed mapping; ESC-motor interfacing and response characteristics. Propulsion Performance - Influence of voltage, propeller characteristics and load conditions on motor performance and efficiency.

Hands on:

1. Propulsion Systems Study: Classification and Performance Characteristics of BLDC Motors and KV Rating Analysis
2. Electronic Speed Controllers and Signal Processing: Analysis of PWM Control and Motor Response Characteristics

Applications	Given a target payload of 500 g and a flight time of 15 minutes, select a suitable BLDC motor, ESC, and propeller combination. Justify the selection using manufacturer datasheets and KV-RPM calculations.

MODULE-4	**SIMULATION, VISUALIZATION AND REAL-TIME SYSTEMS**	**24MEE54.4**	**8 Hours**

Embedded Platforms - Arduino and Raspberry Pi architectures; microcontrollers versus single-board computers; GPIO interfacing; Arduino IDE environment and basic programming workflow.
Sensors - IMU fundamentals (accelerometer, gyroscope, magnetometer); GPS working principles and trilateration; sensor integration concepts; interpretation of orientation and navigation data.
Communication Systems - Radio transmitter-receiver architecture; channel mapping; Frequency-Hopping Spread Spectrum (FHSS); telemetry systems; communication link establishment and signal routing.

Hands on:

1. Microcontroller Platforms in Drone Systems: Comparative Study of Arduino and Raspberry Pi Architectures
2. Sensor Systems and Navigation: Study of IMU and GPS Module Working Principles
3. Communication Systems: Analysis of Radio Transmitter–Receiver Systems

Self-study	Investigate sensor fusion techniques (complementary filter, Kalman filter) used to combine accelerometer and gyroscope data for stable attitude estimation. Prepare a one-page technical note with a block diagram.
Text Book	Text Book 1: Chapter 3; Text Book 2: Section 4.1, 4.2, 4.3

MODULE-5	**PERFORMANCE TESTING, SYSTEM INTEGRATION AND AI IN UAV SYSTEMS**	**24MEE54.5 24MEE54.6**	**8 Hours**

Aerodynamic Performance - Static thrust measurement; effect of propeller diameter and pitch; propulsion efficiency and performance characterization.
Energy Systems - Li-Po battery parameters; C-rating; discharge behaviour; flight endurance estimation; comparison of theoretical and observed performance.
System Integration - Assembly and integration of UAV subsystems; pre-flight inspection; diagnostic procedures; controlled take-off, hovering and basic manoeuvres; stability and control behaviour.
Regulations and Safety - DGCA drone classifications and operational categories (Nano, Micro, Small, Medium, Large); Green, Yellow, and Red zones; Digital Sky Platform; safety guidelines for laboratory, electrical,

mechanical and flight operations; PPE requirements and emergency procedures; laboratory equipment familiarisation.

Hands on:

1. Aerodynamic Performance Characterization: Empirical Analysis of Static Thrust Across Different Propeller Configurations
2. Energy Systems and Mission Planning: Evaluation of Battery Discharge Characteristics and Flight Endurance Estimation
3. System Integration and Operational Demonstration: Drone Assembly Overview, Pre-Flight Diagnostics, and Controlled Take-off

Case Study	Survey: Investigate one published application of AI in commercial drone operations. Summarise the AI technique used, performance metrics, and regulatory compliance measures.

CIE Assessment Pattern (50 Marks – Theory) –

RBT Levels		Marks Distribution	
		Test (s)	Weekly Assessment
		20	30
L1	Remember	-	-
L2	Understand	-	10
L3	Apply	10	10
L4	Analyze	10	10
L5	Evaluate	-	-
L6	Create	-	-

SEE Assessment Pattern (50 Marks – Theory)

RBT Levels		Exam Marks Distribution (50)
L1	Remember	05
L2	Understand	05
L3	Apply	20
L4	Analyze	20
L5	Evaluate	-
L6	Create	-

Suggested Learning Resources:

Text Books:

1) Paul Gerin Fahlstrom, Thomas James Gleason, Mohammad H. Sadraey, "Introduction to UAV Systems", Fifth Edition, Publisher: John Wiley & Sons Inc, 2022, ISBN : 978-1119802617

2) T. Hikmet Karakoc, Emre Özbek, "Unmanned Aerial Vehicle Design and Technology", Publisher: Springer, 2023, ISBN: 978-3-031-45321-2

Reference Books:

1) Garvit Pandya, "Basics of Unmanned Aerial Vehicles : Time to start working on Drone Technology", Publisher: Notion Press Media Pvt Ltd, 2021, ISBN : 978-1637453865

2) Hao Liu, Deyuan Liu, Yan Wan, Kimon Valavanis, Frank Lewis, "Robust Formation Control for Multiple Unmanned Aerial Vehicles", Publisher: CRC Press, 2020, ISBN: 9781032150246

Web links and Video Lectures (e-Resources):

- DGCA (Directorate General of Civil Aviation) Drone Rules 2021: https://dgca.gov.in/digigov-portal/
- NPTEL - Design of Fixed Wing Unmanned Aerial Vehicles and UAV Design - Part II.: https://nptel.ac.in
- Assembling of Electrical Components of Drone - https://drone-iitd.vlabs.ac.in/exp/assembling-electrical-components/
- Drone repairing and maintenance – I - https://drone-iitd.vlabs.ac.in/exp/drone-repairing-and-

maintenance-i/

- Drone's Take-off, Flight and Landing Basics - https://drone-iitd.vlabs.ac.in/exp/drones-take-off-flight-landing-basics/
- Assembling of Software-Based Components of a Drone - https://drone-iitd.vlabs.ac.in/exp/assembling-software-based-components/

Activity-Based Learning (Suggested Activities in Class)/ Practical Based learning

- **Reverse Engineering Teardown Discussion** – Analyse a crashed or retired drone. Students examine the failure mode (broken arm, burnt ESC, damaged propeller) and discuss root cause, what pre-flight check would have caught it, and how it maps to DGCA safety protocols.
- **Propeller Matching Challenge** - Given three different propeller sizes and three motor KV ratings on the bench, students must match each propeller to the correct motor based on thrust requirements and voltage without using any tools, only calculation.
- **Live Telemetry Interpretation** - During a flight session, instructor streams telemetry data (battery voltage, altitude, attitude angles) on a laptop. Students record values at hover, identify anomalies, and correlate IMU readings with observed drone behaviour.
- **DGCA Zone Mapping Exercise** - Using the Digital Sky app or a printed map of the college vicinity, students identify green, yellow, and red zones around the campus, determine what permissions are needed for a hypothetical delivery mission, and fill in a one-page operational clearance summary sheet.

RESEARCH METHODOLOGY AND IPR

Course Code	**24RMK55**	**CIE Marks**	**50**
L: T: P: S	**1:0:0:0**	**SEE Marks**	**50**
Hours / Week	**01**	**Total Marks**	**100**
Credits	**01**	**Exam Hours**	**02**

Course outcomes:
At the end of the course, the student will be able to:

24RMK55.1	Define research problems and formulate research questions and research objectives.
24RMK55.2	Demonstrate research processes, critical thinking, and academic writing skills.
24RMK55.3	Understand the statutory provisions and different forms of Intellectual Property Rights (IPRs).
24RMK55.4	Identify the significance and procedures of patents, including patent filing and protection.

Mapping of Course Outcomes to Program Outcomes and Program Specific Outcomes:

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
24RMK55.1	3	3	2	2	2	–	–	1	2	–	2
24RMK55.2	3	3	2	2	2	–	–	1	2	–	2
24RMK55.3	3	3	2	1	1	–	1	1	2	–	2
24RMK55.4	3	3	2	1	–	–	1	1	2	–	2

MODULE-1	**FORMULATION OF RESEARCH PROBLEM**	**24RMK55.1**	**3 Hours**

Research– Meaning and Objectives–Types of Research–Research Approaches-Research Process–Literature Review–Research Problem– Identification and Defining the Research Problem.

Text Book	Text Book 1: Ch. 1, 2

MODULE-2	**RESEARCH DESIGN PROCEDURES**	**24RMK55.2**	**3 Hours**

Meaning of Research Design – Features of a Good Design –Concepts Related to Research Design– Different Research Designs – Basic Principles of Experimental Designs.

Case Study	To find the solution for the given research problem using different types of research methods
Text Book	Text Book 1: Ch. 3

MODULE-3	**INTERPRETATION AND REPORT WRITING**	**24RMK55.1 24RMK55.2**	**3 Hours**

Meaning and Technique of Interpretation – Precautions in interpretation – Different Steps in Report Writing – Layout of a Research Report– Types of Report – Mechanics of Writing a Research Report –Conclusion-Referencing in Academic Writing –Bibliography.

Text Book	Text Book 2: Ch. 14

MODULE-4	**INTRODUCTION TO IPR**	**24RMK55.3**	**3 Hours**

Introduction and Significance of Intellectual Property Rights –Types of Intellectual Property Rights–Rationale for Protection of IPR–IPR in India and Abroad–Forms of IPR – Royalty – Copyright – Trademark – Patents – Industrial Designs –Application of Different Forms of IPR– Future Aspects of IPR– Some Examples of IPR.

Text Book	Text Book 2: Ch. 1 and 2

MODULE-5	BASICS OF PATENTS	24RMK55.3, 24RMK55.4	3 Hours

Patents and its Basics – Patentable and Non-Patentable Inventions–Patent Application Process (National and International level) –Drafting and Filing a Patent –Types of Patent Applications–Patent Documents–Specification and Claims–Assignment, Licensing, Infringement–Different Layers of International Patent System

Case Study	Analyze different domains of filed patents
Text Book	Text Book 2: Ch. 1 and 2

CIE Assessment Pattern (50 Marks – Theory)

RBT Levels		Marks Distribution		
		Test (s)	Patent drafting	Review paper writing
		25	15	10
L1	Remember	5	-	-
L2	Understand	5	-	-
L3	Apply	5	-	-
L4	Analyze	5	5	5
L5	Evaluate	5	5	5
L6	Create	-	5	-

SEE Assessment Pattern (50 Marks – Theory)

RBT Levels		Exam Marks Distribution (50)
L1	Remember	10
L2	Understand	10
L3	Apply	10
L4	Analyze	10
L5	Evaluate	10
L6	Create	--

Suggested Learning Resources:

Text Books:

1) Kothari, C.R., Research Methodology: Methods and Techniques, New Age International, 2024, ISBN-9789389802559
2) Ramakrishna Chintakunta, A Text book of Intellectual Property rights, Blue Hill Publication, ASIN: B09T6YDB5N, 2022

Reference Books:

1) Garg, B.L., Karadia, R., Agarwal, F. and Agarwal, U.K, An Introduction to Research Methodology, RBSA Publishers. 2022, ISBN-13:978-8176111652
2) Ranjith Kumar, Research methodology, Saga publications,5th edition, 2024, ISBN- 9781529788785.
3) Sinha, S.C. and Dhiman, A.K., Research Methodology, EssEss Publications. 2 volumes, 2022. ISBN: 81-7000-324-5(Vol-I), 81-7000-334-2 (Vol-II)
4) Asha Vijay Durafe, Dhanashree K. Toradmalle , Intellectual Property Rights, Dreamtech Press,2024, ISBN: 9789351195191.

Web links and Video Lectures (e-Resources):

- https://www.youtube.com/watch?v=GSeeyJVD0JU
- https://www.youtube.com/watch?v=nv7MOoHMM2k
- https://www.youtube.com/watch?v=BGSgZ1J8-yQ
- https://onlinecourses.nptel.ac.in/noc22_ge08/preview
- https://www.coursera.org/learn/research-methods

• https://www.wipo.int/academy/en/
Activity-Based Learning (Suggested Activities in Class)/ Practical Based learning • Video Sessions • Organizing Group Wise Discussions • Paper Presentation • Review paper writing • Patent drafting

PROBLEM SOLVING METHODOLOGIES

Course Code	**24SDK56**	**CIE Marks**	**50**
L:T:P:S	**0:0:1:0**	**SEE Marks**	**-**
Hrs / Week	**2**	**Total Marks**	**50**
Credits	**1**	**Exam Hours**	**02**

Course outcomes:
Upon successful completion of this course, the student will be able to:

24SDK56.1	Demonstrate proficiency in solving quantitative aptitude problems using fundamental concepts
24SDK56.2	Apply advanced quantitative techniques to address and solve complex real-world problems.
24SDK56.3	Develop and enhance logical reasoning skills essential for problem-solving in various competitive examinations.
24SDK56.4	Cultivate critical and creative thinking skills necessary for analytical reasoning and problem-solving.

Mapping of Course Outcomes to Program Outcomes and Program Specific Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
24SDK56.1	3	3	-	-	2	-	-	-	-	-	-
24SDK56.2	3	3	-	-	2	-	-	-	-	-	-
24SDK56.3	3	3	-	-	2	-	-	-	-	-	-
24SDK56.4	3	3	-	-	2	-	-	-	-	-	-

MODULE-1	**Critical Thinking through Quantitative Analysis**	**24SDK56.1 24SDK56.2**	**6 Hours**

Number systems: LCM and HCF of numbers, Squaring and Cubing Techniques, Multiplication Tricks, Divisibility rules, Digit sum method, Speed Math, Simplifications, Approximations.

Percentages: Conversion of Fraction to Percentage Table, Percentage Change, Net percentage change/Effective percentage change, Successive Percentage, Concept of more/less percentage, Percentage of percentage, Product constancy, Increased/decreased by P%, Percentage Changes in Numerator and Denominator, Successive Percentage.

Averages: Basic concept, Consecutive Numbers, Non-Consecutive Numbers, Equation Concept, True/False concept, Including/Excluding concept, Replacement concept, Average Speed concept.

MODULE-2	**Numerical Techniques for Problem Solving**	**24SDK56.1 24SDK56.2**	**6 Hours**

Profit and Loss: Basic concept, Profit Percentage, Loss Percentage, Profit/Loss Percentage, Overall Profit/Loss, Dishonest shopkeeper, More/less loss concept, Discounts **Ratio and Proportion:** Concept Explanation, Duplicate Ratio, Triplicate Ratio, Direct Proportion, Indirect Proportion, Double rule of three or compound proportion, Ratio in investment, Ratio in partnership, Ratio in averages, Ratio in profit and loss, Ratio in interest rates. **Ages:** Ratio and sum of ages, Ratio and Product of Ages, Ratio of Present and Future Ages, Ratio of Past and Present Ages. **Partnership:** Simple Partnership, Compound Partnership, Partnership at Will, Partnership for a Fixed Term, Particular Partnership, General Partnership, Limited Partnership, Limited Liability Partnership.			
MODULE-3	**Quantitative Techniques**	**24SDK56.1** **24SDK56.2**	**6 Hours**
Time and Work: Unit work, Combined work, Individual efficiency, Group efficiencies, Time taken by an individual or a group, Work done by an individual or a group, Total work done, Chain Rule Concept, Pipes and Cisterns, 4 Rules of Pipes and Cistern. **Gamification:** Switch Grid, Geo Sudoku, Grid Lock, Number Challenge, Cognitive reasoning games.			
Cognitive Ability: Statements & Conclusions, Statements & Assertions, Statements & Assumptions, Causes & Effects and Flow Charts.			
MODULE-4	**Analytical Reasoning and Creative Problem Solving**	**24SDK56.3** **24SDK56.4**	**6 Hours**
Number Series - Missing numbers, Incomplete series - Odd-even series, primes, Fibonacci series, Arithmetic progression, Geometric progression, Harmonic progression, Squares and cubes, Operations on digits, Exponential series, Increasing multiplication, Hybrid series. **Alphabetical Series**- Missing alphabets, incomplete letter series - series of words, series of letters, arrangement of words/letters, letters marked with corresponding numbers sequence, positions of letters, ranking of the word in dictionary; Mixed Series - Missing numbers and words/letters, complete the series. **Analogies:** Alphabet Classification, Word Classification, Number Classification. **Coding and Decoding:** Coding based on order, Letter to Letter Mapping, Letter to number mapping, Letter to digit mapping, Re-ordering sequences; Word sequencing, Match the word to code, Symbol Coding.			
MODULE-5	**Problem Solving through Logical Analysis**	**24SDK56.3** **24SDK56.4**	**6 Hours**
Directions: Eight Directions, Distance, Displacement, Starting and ending points, Referential directions, Directions of shadows, Axis based problems, Actual and conditional directions. **Seating Arrangements:** Linear arrangement, Square Arrangement, Rectangular Arrangement, Circular arrangement, Vertical arrangement, Seating arrangement in a photograph, Tabular arrangement, Hexagonal Seating Arrangement, Complex arrangement, Miscellaneous arrangements. **Blood Relations:** Relations defined, Generation Verticals, Family Tree, Single Person Blood Relations, Mixed/Chain Blood Relations, Symbol based Blood Relation.			

CIE Assessment Pattern (50 Marks – Theory)

RBT Levels		Marks Distribution
		Tests
		50
L1	Remember	10
L2	Understand	10
L3	Apply	20
L4	Analyze	10
L5	Evaluate	-
L6	Create	-

Suggested Learning Resources:

Text Books:

1. Quantitative Aptitude for Competitive Examinations — R.S. Aggarwal
2. How to Prepare for Quantitative Aptitude for CAT — Arun Sharma

Reference Books:

1. Quantum CAT — Sarvesh K. Verma
2. Fast Track Objective Arithmetic — Rajesh Verma
3. Quantitative Aptitude for Placements — Dinesh Khattar

Web links and Video Lectures (e-Resources):

- Freshersworld: Aptitude & Reasoning https://www.youtube.com/results?search_query=Freshersworld+Aptitude+Reasoning
- Adda24/7: Aptitude & Reasoning https://www.youtube.com/results?search_query=Adda247+Quantitative+Aptitude+Reasoning

Activity-Based Learning (Suggested Activities in Class)/ Practical Based learning

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Activity	Aptitude Topic	Description
Math Relay Race	Percentages, Profit & Loss, Time & Work	➢ Divide students into teams. Each student solves one question and passes the sheet to the next teammate. The first team to finish with the most correct answers wins.
Puzzle & Seating Challenge	Seating Arrangements, Logical Reasoning	➢ Give each team a seating arrangement or logic puzzle. Teams compete to solve it within a fixed time.
DI Detective	Data Interpretation	➢ Provide charts, graphs, or tables. Students answer questions individually or in groups, explaining how they arrived at their answers.
Human Number Line	Number System, Averages, Ratio & Proportion	➢ Students hold number cards and physically arrange themselves to solve ordering, averages, ratios, or sequence-based problems.

Aptitude Quiz Bowl	Mixed Aptitude Topics	➢ Conduct a quiz with multiple rounds (MCQs, rapid fire, visual reasoning, puzzles, and calculation challenges). Award points to teams and maintain a leaderboard.

SOCIETAL BASED MINI PROJECT			
Course Code	**24MEE57**	**CIE Marks**	**50**
L: T:P:S	**0:0:1:0**	**SEE Marks**	**50**
Hrs / Week	**2**	**Total Marks**	**100**
Credits	**01**	**Exam Hours**	**03**

Course outcomes:

At the end of the course, the student will be able to:

24MEE57.1	Identify and formulate real-world societal problems through field surveys, literature reviews, and interaction with local communities.
21MEE57.2	Apply fundamental engineering principles and innovative technologies to design sustainable, cost-effective solutions for societal challenges.
21MEE57.3	Utilize modern engineering tools, software, and hardware to model, develop, and test the functional prototype.
21MEE57.4	Communicate project findings and technical specifications effectively through comprehensive documentation and professional presentations.
21MEE57.5	Demonstrate team dynamics, project management skills, and professional ethics while executing the project within defined time and budget constraints.
21MEE57.6	Review existing literature and technological solutions to justify the scope and relevance of the proposed societal project.

Mini Project Roadmap: Guiding Principles for Societal based **Mini Project Success**

Project Overview:

- Clearly define the project's scope, objectives, and expected outcomes.
- Provide a brief description of the problem the project aims to solve or the functionality it should implement.

Project Milestones:

- Set clear project milestones and deadlines for various phases, such as planning, design, implementation, testing, and presentation.

Project Requirements:

- List the specific features or functionality that students need to implement in their projects.
- Clearly state any constraints or limitations they should be aware of during development.

Testing and Quality Assurance:

- Incorporate testing practices into their development process.
- Specify the types of testing (e.g., unit testing, integration testing)

Collaboration and Communication:

- If the project involves teamwork, outline expectations for collaboration, including communication channels and responsibilities within the team.

Documentation:

- Emphasize the importance of thorough documentation throughout the project.
- Require students to maintain documentation for code, design, and usage instructions.

Presentation:

- Require students to present their projects to the class, explaining their design choices, challenges faced, and how they overcame them.

Text Book	Text Book 1 & 2

CIE Assessment Pattern (50 Marks – Reviews as per the rubric statements defined)

RBT Levels		Exam Marks Distribution (50)
L1	Remember	-
L2	Understand	-
L3	Apply	20
L4	Analyze	10
L5	Evaluate	10
L6	Create	10

SEE Assessment Pattern (50 Marks – Theory)

RBT Levels		Exam Marks Distribution (50)
L1	Remember	-
L2	Understand	-
L3	Apply	20
L4	Analyze	10
L5	Evaluate	10
L6	Create	10

Suggested Learning Resources:

Text Books:

1)Kothari, C.R.,Research Methodology: Methods and Techniques. New Age International. 2018, ISBN-13: 978-8122436235

2) Garg, B.L., Karadia, R., Agarwal, F. and Agarwal, U.K., , An introduction to Research Methodology, RBSA Publishers. 2015, ISBN-13: 978-8176111652

3) Ranjithkumar, research methodology, saga publications,4th edition ,2014, ISBN-13- 978- 9351501336

Reference Books:

1).Anderson, T. W. An Introduction to Multivariate Statistical Analysis, Wiley Eastern Pvt., Ltd., New Delhi. 2011, ISBN-13: 978-8126524488

2) Montgomary, Douglas C. &Runger, George C. Applied Statistics & probability for Engineers (Wiley India) 2016, ISBN-13: 978-1118539712

Web links and Video Lectures (e-Resources):

- https://www.youtube.com/watch?v=YScxVF6ZcYI
- https://www.youtube.com/watch?v=9WMgaulAJ-0

Activity-Based Learning (Suggested Activities in Class)/ Practical Based learning

These challenging mini project activities can provide students with opportunities to think critically, apply their knowledge, and develop problem-solving skills in a practical context.

Interdisciplinary Projects:

- Encourage collaboration among students from different disciplines to work on projects that require diverse expertise.

Prototype Development:

- Challenge students to create a prototype of a product or device.

Simulation and Modelling:

- Task students with creating computer simulations or mathematical models to solve complex problems or simulate real-world scenarios.

Humanitarian and Social Impact Projects:

- Challenge students to develop projects that address social or humanitarian issues, such as providing clean water solutions, designing low-cost healthcare devices, or improving education in underserved communities.

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Environmental Sustainability Projects:

- Challenge students to propose and implement sustainability initiatives or renewable energy projects.

Scientific Research Projects:

- Assign students to conduct scientific research experiments, gather data, and present findings.

VI Semester Syllabus

ROBOTICS AND DIGITAL TWIN TECHNOLOGY

Course Code	**24MEE61**	**CIE Marks**	**50**
L:T:P:S	**3:0:0:0**	**SEE Marks**	**50**
Hrs / Week	**3**	**Total Marks**	**100**
Credits	**03**	**Exam Hours**	**03**

Course outcomes:

At the end of the course, the student will be able to:

24MEE61.1	Explain the fundamental concepts, classification, configurations, anatomy, and performance characteristics of industrial robots and the architecture, components, and lifecycle of Digital Twin technology.
24MEE61.2	Apply the principles of robot drive systems, transmission mechanisms, end effectors, and kinematic representations for the analysis of robotic systems
24MEE61.3	Analyze the applications of sensors, machine vision, and AI-based techniques such as CNN, YOLO, point-cloud processing, and sensor fusion for robotic perception.
24MEE61.4	Develop and simulate Digital Twin models using 3D modelling, CAD integration, real-time data acquisition, and physical–virtual synchronization
24MEE61.5	Analyze Digital Twin systems using IoT, cloud and edge computing, AI/ML, predictive analytics, simulation, and real-time data integration
24MEE61.6	Develop Digital Twin-based solutions incorporating optimization, anomaly detection, predictive maintenance, lifecycle management, interoperability, and cybersecurity for smart manufacturing and Industry 4.0.

Mapping of Course Outcomes to Program Outcomes and Program Specific Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2
24MEE61.1	3	2	2	-	-	-	-	-	-	-	-	3	2
24MEE61.2	3	2	2	-	-	-	-	-	-	-	-	3	2
24MEE61.3	3	2	2	2	3	-	-	-	-	-	-	3	3
24MEE61.4	3	3	2	-	2	-	-	-	-	-	-	3	3
24MEE61.5	3	3	2	-	2	-	-	-	-	-	-	3	2
24MEE61.6	2	2	2	-	1	2		1	1	1	1	2	1

MODULE-1	**INTRODUCTION TO ROBOTICS AND DIGITAL TWIN**	**24MEE61.1**	**8 Hours**

History, evolution, classification, anatomy, configurations and performance characteristics of industrial robots; fundamentals, components, architecture, types and lifecycle of Digital Twins; physical and virtual twins, Digital Thread, data acquisition, IoT, AI and simulation, and applications in robotics and smart manufacturing.

Case Study	Industrial robots integrated with Digital Twin technology.
Text Book	Text Book 1: 1.2,1.3,1.4,1.5

MODULE-2	**ROBOT DRIVE SYSTEMS AND KINEMATICS**	**24MEE61.2**	**8 Hours**

Hydraulic, pneumatic and electric drives, transmission systems, end effectors and gripper selection; position and orientation, homogeneous transformation matrices, D-H representation, forward and inverse kinematics of 2-DOF and 3-DOF manipulators.

Case Study	Investigate the selection of suitable end effectors for material handling, assembly and welding operations.
Text Book	Text Book 1: 2.2,2.4,2.5,2.7,2.9

MODULE-3	**SENSORS, MACHINE VISION AND AI PERCEPTION**	**24MEE61.3, 24MEE61.4**	**8 Hours**

Tactile, proximity, range, force, torque, LiDAR and depth sensors; machine vision, image processing, segmentation and feature extraction; CNN, YOLO, object detection, point-cloud processing and sensor fusion for robotic perception

Self-study	AI-based object detection and robotic inspection.

Text Book	Text Book 2: 3.1,3.2,3.4,3.6,3.8		
MODULE-4	**DIGITAL TWINS FOR ROBOTIC SYSTEMS**	**24MEE61.5**	**8 Hours**
Digital Twin architecture, 3D modelling, virtual robotic work cells, CAD integration, robot simulation, real-time data acquisition, physical–virtual synchronization, performance monitoring and virtual commissioning			
Case Study	Develop and simulate a Digital Twin of a robotic system using suitable simulation software.		
Text Book	Text Book 1:5.1,5.2,.5.5.,5.8		
MODULE-5	**ADVANCED DIGITAL TWIN CONCEPTS AND APPLICATIONS**	**24MEE61.6**	**8 Hours**
Digital Twin development and implementation, Digital Thread, real-time data integration, IoT-enabled Digital Twins, cloud and edge computing, AI/ML integration, data synchronization, predictive analytics, virtual commissioning, simulation-based optimization, anomaly detection, predictive maintenance, Digital Twin lifecycle management, interoperability, cybersecurity, and applications of Digital Twins in smart manufacturing and Industry 4.0			
Activity	Develop a basic Digital Twin model, establish real-time data synchronization, perform virtual simulation, monitor system performance, and implement predictive analysis using suitable Digital Twin platforms.		
Text Book	Text Book 2: 7.1,7.2,7.4,7.6,7.9		

CIE Assessment Pattern (50 Marks – Theory) –

RBT Levels		Marks Distribution		
		Test (s)	AAT1	AAT2
		25	15	10
L1	Remember	5	-	-
L2	Understand	5	5	-
L3	Apply	10	5	5
L4	Analyze	5	5	5
L5	Evaluate	-	-	-
L6	Create	-	-	-

SEE Assessment Pattern (50 Marks – Theory)

RBT Levels		Exam Marks Distribution (50)
L1	Remember	10
L2	Understand	10
L3	Apply	20
L4	Analyze	10
L5	Evaluate	--
L6	Create	--

Suggested Learning Resources:

Text Books

1. R.K. Mittal and I.J. Nagrath, "Robotics and Control", McGraw Hill Education, Reprint 2021, ISBN: 9789339204374.
2. Mikell P. Groover, Mitchell Weiss, Roger N. Nagel and Nicholas G. Odrey, "Industrial Robotics: Technology, Programming and Applications", McGraw Hill Education, Reprint 2021, ISBN: 9781259006210.

Reference Books

1. Saeed B. Niku, "Introduction to Robotics: Analysis, Control, Applications", Wiley, 3rd Edition, 2021, ISBN: 9781119527629.
2. John J. Craig, "Introduction to Robotics: Mechanics and Control", Pearson Education, 4th Edition, 2022. ISBN-13: 9780133489798
3. Bruno Siciliano and Lorenzo Sciavicco, "Robotics: Modelling, Planning and Control", Springer, Latest Edition. 2009, ISBN-13: 9781846286414

Web links and Video Lectures (e-Resources):

- https://nptel.ac.in/courses/112106298
- https://nptel.ac.in/courses/112101098
- https://ocw.mit.edu/courses/mechanical-engineering/
- https://www.universal-robots.com/academy/
- https://www.fanuc.eu/in/en/education

Activity-Based Learning (Suggested Activities in Class)/ Practical Based learning

Study and demonstration of industrial robot configurations.
• Case study on robotic material handling and welding applications.
• Kinematic analysis of simple robot manipulators.
• Simulation of robot motion using robotic software tools.
• Industrial survey on robot applications in manufacturing.

ROBOTICS AND DIGITAL TWIN LAB

Course Code	**24MEL61**	**CIE Marks**	**50**
L:T:P:S	**0:0:1:0**	**SEE Marks**	**50**
Hrs / Week	**2**	**Total Marks**	**100**
Credits	**01**	**Exam Hours**	**03**

Course outcomes:

At the end of the course, the student will be able to:

24MEL61.1	Develop and control basic robotic systems using microcontrollers, motors, actuators, and robotic mechanisms.
24MEL61.2	Integrate sensors, communication modules, and embedded systems for autonomous and remotely controlled robotic applications.
24MEL61.3	Implement robotic systems using sensor feedback, IoT connectivity, and intelligent control techniques.
24MEL61.4	Develop and analyze virtual robotic models and Digital Twin applications using simulation, real-time data, monitoring, and performance analysis.

Mapping of Course Outcomes to Program Outcomes and Program Specific Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2
24MEL61.1	3	3	3	3	3	-	3	-	-	-	-	3	3
24MEL61.2	3	2	3	3	2	-	3	3	-	-	3	2	2
24MEL61.3	3	2	2	2	2	-	2	2	2	2	2	2	2
24MEL61.4	3	3	1	2	2	-	2	-	1	2	1	3	2

Pgm. No.	List of Programs	Hours	COs
	Prerequisite Programs		
	• Verification of basic gates using IC Trainer board • Basic gate implementation using Verilog code.	2	NA
	PART-A		
1	Design and implementation of a pick-and-place robotic arm using servo motors and a gripper mechanism	2	24MEL6.1
2	Develop **a** web-controlled IoT robotic arm using ESP32 for remote operation	2	24MEL6.1
3	Develop a Bluetooth-controlled mobile robot using microprocessor and implement directional/motor control	2	24MEL6.1
4	Develop an RF-controlled robotic system using RF transmitter–receiver modules	2	24MEL6.1
5	Develop an obstacle-avoiding robot using PI and ultrasonic sensors	2	24MEL6.2
6	Develop a human-following robot using PI and ultrasonic sensing	2	24MEL6.2
	PART-B		
7	Develop and simulate a virtual robotic system using BrowserBotics and study its joints, motion and workspace	2	24MEL6.2
8	Develop a virtual pick-and-place system and perform trajectory and path-planning simulation using BrowserBotics	2	24MEL6.2
9	Develop a Digital Twin of a component-based robotic system and establish virtual model–data synchronization	2	24MEL6.3
10	Implement Digital Twin-based real-time monitoring of position,	2	24MEL6.3

	velocity and sensor parameters using simulated data		
11	Perform Digital Twin-based anomaly detection and predictive maintenance using simulated sensor data	2	24MEL6.4
12	Perform virtual commissioning of a component-based robotic system using BrowserBotics and validate its programmed sequence	2	24MEL6.4

PART-C
Beyond Syllabus Virtual Lab Content
(To be done during Lab but not to be included for CIE or SEE)

- **Forward Kinematics of 5R Robot Manipulator**
  IIT Kharagpur Robotics & Control Virtual Lab
- **Forward Kinematics of 6R Robot Manipulator**
  IIT Kharagpur Robotics & Control Virtual Lab Experiments
- **Inverse Kinematics of a 6R Robot**
  IIT Kharagpur Robotics & Control Virtual Lab
- **Robot Teaching Using VAL Programming**
  Mechanisms and Robotics Lab, IIT Kharagpur
- **PUMA 560 Robot Simulation**
  Mechanisms and Robotics Lab, IIT Kharagpur
- **Industrial Robot Programming and Simulation**
  Virtual Labs India Portal

CIE Assessment Pattern (50 Marks – Lab)

RBT Levels		Test (s)	Weekly Assessment
		20	30
L1	Remember	-	-
L2	Understand	-	10
L3	Apply	10	10
L4	Analyze	10	10
L5	Evaluate	-	-
L6	Create	-	-

SEE Assessment Pattern (50 Marks – Lab)

RBT Levels		Exam Marks Distribution (50)
L1	Remember	05
L2	Understand	05
L3	Apply	20
L4	Analyze	20
L5	Evaluate	-
L6	Create	-

Suggested Learning Resources:
Reference Books:

1. Saeed B. Niku, "Introduction to Robotics: Analysis, Control, Applications", 3rd Edition, Wiley, 2021, ISBN: 9781119527629.
2. Bruno Siciliano, Lorenzo Sciavicco, Luigi Villani and Giuseppe Oriolo, "Robotics: Modelling, Planning and Control", Springer, Reprint 2021, ISBN: 9781846286416.
3. John J. Craig, "Introduction to Robotics: Mechanics and Control", 4th Edition, Pearson Education, 2022, ISBN: 9780133489790.
4. Mikell P. Groover, "Automation, Production Systems and Computer Integrated Manufacturing", 5th Edition, Pearson, 2022, ISBN: 9781292441575.

FINITE ELEMENT METHODS

Course Code	**24MEE62**	**CIE Marks**	**50**
L:T:P:S	**3:0:0:0**	**SEE Marks**	**50**
Hrs / Week	**3**	**Total Marks**	**100**
Credits	**03**	**Exam Hours**	**03**

Course outcomes:

At the end of the course, the student will be able to:

24MEE62.1	Understand the fundamental concepts, formulations and interpolation techniques of FEM, FE procedure, Interpolations, paraphrase numerical methods
24MEE62.2	Develop the desirable characteristics of one dimensional and 2-D element
24MEE62.3	Analyze the problem for applying boundary conditions for 1D elements
24MEE62.4	Apply suitable boundary conditions to a global equation for trusses
24MEE62.5	Determine beam deflections and related unknown field variables to assess the structural response of beam structures
24MEE62.6	Design the dynamic response characteristics of structures through Eigen value analysis and model interpretation

Mapping of Course Outcomes to Program Outcomes and Program Specific Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2
24MEE62.1	3	3	3	3	-	-	-	-	-	-	-	-	3
24MEE62.2	3	3	3	3	-	-	-	-	-	-	-	-	3
24MEE62.3	3	3	3	3	-	-	-	-	-	-	-	-	3
24MEE62.4	3	3	3	3	-	-	-	-	-	-	-	-	3
24MEE62.5	3	3	3	3	-	-	-	-	-	-	-	-	3
24MEE62.6	3	3	3	3	-	-	-	-	-	-	-	-	3

MODULE-1	**INTRODUCTION TO FINITE ELEMENT METHODS**	**24MEE62.1**	**8 Hours**

Introduction to Finite Element Methods:

Basic Concept, Historical background, General and Engineering applications of the FEM, Advantages, Classification, Basic steps, Types of elements based on Geometry, bandwidth, Variation formulations using Rayleigh Ritz method and weighted residual methods. Basic Equations and Potential Energy Functional, Numericals.

Interpolation Models: Introduction, Polynomial form of interpolation function, Simplex, Complex, and Multiplex elements, Interpolation polynomial in terms of nodal DOF, Selection of the order of the interpolation polynomial, Convergence requirements, coordinate systems

Case Study	Problem solving on Numerical Integration.
Text Book	Text Book 1: 1.1 to 1.15

MODULE-2	**1-D AND 2-D ELEMENTS**	**24MEE62.2**	**8 Hours**

Shape functions and its properties, Derivation of Shape functions in Global, Local and Natural Co-ordinate systems. Shape functions for Triangular and Quadrilateral element.Iso Parametric,Sub Parametric and Super Parametric elements, Strain Displacement matrix for Triangular
and Quadrilateral Elements, Numericals on Isoparametric Formulation and Jacobian Matrix.

Case Study	Shape functions for various Higher order elements.
Text Book	Text Book 1: 3.1to 3.11,6.1-6.4

MODULE-3	**SOLUTION OF 1-D PROBLEMS**	**24MEE62.3**	**8 Hours**

Definition, Properties of a stiffness matrix and derivation of Stiffness matrix for 1-D bar element, Essential and Non Essential Boundary conditions, Problems using Elimination and Penalty approach on various loading conditions for Constant cross section ,Tapered cross section and bar with a Gap, Temperature effect on Bar

Application	Evaluation of Stresses and field variables of structures using ANSYS software.
Text Book	Text Book 1:3.1-3.10

MODULE-4	**STRUCTURAL ANALYSIS THROUGH FEM FOR BEAMS AND TRUSSES**	**24MEE62.4 24MEE62.5**	**8 Hours**

Beams: 2-Noded beam element, Finite element formulation, load vector, point load, UDL, shear force and bending moment, Deflection equation, shape functions and stiffness matrixes.
Trusses: Includes study of problems with one, two, three and four bar elements, Equation of truss, stiffness matrix derivation, and assumptions.

Case Study	Determination of Field variables related to Frames and Axisymmetric problems.
Text Book	Text Book 1: 4.1-4.5,5.1-5.3 Text Book 2: 10.1, 10.3, 10.5, 10.7

MODULE-5	**FEM FOR DYNAMIC ANALYSIS**	**24MEE62.6**	**8 Hours**

FEM for Dynamic: System of springs, Formulation for point mass and distributed masses, Consistent element mass matrix of one dimensional bar element, truss element, quadrilateral element, beam element. Lumped mass matrix, Evaluation of Eigen values and Eigen vectors, Applications to bars, stepped bars, and beams. AI based prediction of natural frequencies of beams using FEM Data

Applications	Practical applications of Dynamic analysis in spring mass system.
Text Book	Text Book 1: 11.1-11.6

CIE Assessment Pattern (50 Marks – Theory)

RBT Levels		Marks Distribution		
		Test (s)	AAT1	AAT2
		25	15	10
L1	Remember	5	-	-
L2	Understand	5	5	-
L3	Apply	10	5	5
L4	Analyze	5	5	5
L5	Evaluate	-	-	-
L6	Create	-	-	-

SEE Assessment Pattern (50 Marks – Theory)

RBT Levels		Exam Marks Distribution (50)
L1	Remember	10
L2	Understand	10
L3	Apply	20
L4	Analyze	10
L5	Evaluate	--
L6	Create	--

Suggested Learning Resources:

Text Books:

1) Chandrupatla T. R. "Introduction to Finite Elements in engineering"- 4th Edition, Pearson, 2016, ISBN-13: 978-0132162746

2) Lakshmi Narayana H. V.,"Finite Elements Analysis"– Procedures in Engineering, Universities Press, 2014, ISBN-13: 978-83714764

Reference Books:

1) Rae S. S. "Finite Elements Method in Engineering"- 4th Edition, Elsevier,2014, ISBN: 9780750678285
2) P.Seshu, "Textbook of Finite Element Analysis" -PHI, 2007, ISBN : 978-81-203-2315-5
3) J.N.Reddy,"Finite Element Method"-McGraw-Hill International Edition. 3rd Ed, 2019, ISBN: 9780070607415

Web links and Video Lectures (e-Resources):

- **https://www.youtube.com/watch?v=UOp6JEiJctA&list=PLSGws_74K018SmggufD-pbzG3thPIpF94**
- **https://www.youtube.com/watch?v=0VNIEfX0m4A&list=PLSGws_74K018SmggufD-pbzG3thPIpF94&index=3**
- **https://www.youtube.com/watch?v=jQPwabwnBpg&list=PLSGws_74K018SmggufD-pbzG3thPIpF94&index=27**
- **https://www.youtube.com/watch?v=1JOMM-ytOyU&list=PLSGws_74K018SmggufD-pbzG3thPIpF94&index=4**

Activity-Based Learning (Suggested Activities in Class)/ Practical Based learning

- Visit to any Design company/aero/auto industry
- Demonstration of Structures using ANSYS software.
- Video demonstration of Stress concentration factor for a plate with a hole.
- Problem solving approaches for the Approximation methods.
- Contents related activities (Activity-based discussions)
- For active participation of students, instruct the students to solve the matrix related numericals.
- Organizing Group wise discussions on issues
- Seminars

FINITE ELEMENT METHOD LAB

Course Code	**24MEL62**	**CIE Marks**	**50**
L:T:P:S	**0:0:1:0**	**SEE Marks**	**50**
Hrs / Week	**2**	**Total Marks**	**100**
Credits	**01**	**Exam Hours**	**03**

Course outcomes:

At the end of the course, the student will be able to:

24MEL62.1	Apply the modern tools to formulate and create geometry for solving problems of bars with different loading condition
24MEL62.2	Analyze boundary condition to determine stress with different loading conditions of a rectangular plate with a hole
24MEL62.3	Analysis of truss members to find displacements and stresses with different loading Conditions and to demonstrate the deflection of beams subjected to draw shear force and bending moment diagrams
24MEL62.4	Apply the Temperature Distribution and Temperature gradient across the Composite wall

Mapping of Course Outcomes to Program Outcomes and Program Specific Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2
24MEL62.1	3	2	2	-	3	-	-	-	-	-	-	-	3
24MEL62.2	3	3	3	-	3	-	-	-	-	-	-	-	3
24MEL62.3	3	3	3	-	3	-	-	-	-	-	-	-	3
24MEL62.4	3	3	3	-	3	-	-	-	-	-	-	-	3

Exp. No.	List of Experiments	Hours	COs
	Prerequisite Experiments		
	• Stress analysis of various structures • Shear Force and Bending Moment Diagrams	2	NA
	PART-A		
1	Determination of displacement of a simple bar with an axial load	2	24MEL62.1
2	Determination of Field variables in Bars of Constant Cross Section	2	24MEL62.1
3	Evaluation of Displacements, Stresses in Bars Of Tapered Cross Section And Stepped Bar	2	24MEL62.1
4	Stress Analysis Of A Rectangular Plate With A Hole	2	24MEL62.2
5	Determination of field variables in 2 bar Trusses.	2	24MEL62.3
6	Determination of field variables in 3 bar Trusses.	2	24MEL62.3
	PART-B		
7	Determination of field variables in Cantilever Beam With Various Loading Conditions	2	24MEL62.3
8	Determination of field variables in Simply Supported Beams With Different Loading Conditions	2	24MEL62.3
9	Thermal Analysis of a Composite wall with the given boundary conditions.	2	24MEL62.4
10	Heat flux analysis of a given Composite wall.	2	24MEL62.4
11	Temperature gradient analysis of a Composite wall.	2	24MEL62.4

12	Thermal Analysis of a fins with the given boundary conditions.	2	24MEL62.4

PART-C

Beyond Syllabus Virtual Lab Content

(To be done during Lab but not to be included for CIE or SEE)

- **Structural Analysis**
  https://mech.l3.nitk.ac.in/course/applied-finite-element-method
- **Non Structural Analysis**
  https://mech.nitk.ac.in/course/finite-element-analysis
- **Solid Element FEM Analysis**
  https://vlabs.iitkgp.ac.in/vlt/phase3_newlab.html?utm_source=chatgpt.com

CIE Assessment Pattern (50 Marks – Lab)

RBT Levels		Test (s)	Weekly Assessment
		20	30
L1	Remember	-	-
L2	Understand	-	10
L3	Apply	10	10
L4	Analyze	10	10
L5	Evaluate	-	-
L6	Create	-	-

SEE Assessment Pattern (50 Marks – Lab)

RBT Levels		Exam Marks Distribution (50)
L1	Remember	05
L2	Understand	05
L3	Apply	20
L4	Analyze	20
L5	Evaluate	-
L6	Create	-

Suggested Learning Resources:

Reference Books:

1)Rae S. S. "Finite Elements Method in Engineering"- 4th Edition, Elsevier, 2014, ISBN: 9780750678285
2)P.Seshu, "Textbook of Finite Element Analysis" -PHI, 2007, ISBN : 978-81-203-2315-5
3)J.N.Reddy,"Finite Element Method"-McGraw-Hill International Edition. 3rd Ed, 2019, ISBN: 9780070607415

COMPUTATIONAL FLUID DYNAMICS

Course Code	**24MEK63**	**CIE Marks**	**50**
L:T:P:S	**3:0:0:0**	**SEE Marks**	**50**
Hrs / Week	**3**	**Total Marks**	**100**
Credits	**03**	**Exam Hours**	**03**

Course outcomes:

At the end of the course, the student will be able to:

24MEK63.1	Explain the governing equations of fluid flow and fundamentals of Computational Fluid Dynamics (CFD).
24MEK63.2	Apply numerical discretization techniques to solve fluid flow equations.
24MEK63.3	Analyze finite difference and finite volume formulations for engineering problems.
24MEK63.4	Apply numerical solution procedures for diffusion and convection-diffusion problems.
24MEK63.5	Solve incompressible fluid flow problems using CFD techniques.
24MEK63.6	Interpret CFD simulation results and utilize CFD software for engineering applications.

Mapping of Course Outcomes to Program Outcomes and Program Specific Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2
24MEK63.1	3	2	1		2	-	-	-	-	-	-	3	2
24MEK63.2	3	3	2		3	-	-	-	-	-	-	3	2
24MEK63.3	3	3	2	2	3	-	-	-	-	-	-	3	3
24MEK63.4	3	3	2	2	3	-	-	-	-	-	-	3	3
24MEK63.5	3	3	2	2	3	-	-	-	-	-	-	3	2
24MEK63.6	2	2	2	1	3	2	-	1	1	1	1	2	1

MODULE-1	**INTRODUCTION TO COMPUTATIONAL FLUID DYNAMICS USING ENERGY2D**	**24MEK63.1**	**8 Hours**

Introduction to CFD, governing equations of heat transfer and fluid flow, computational domain, boundary conditions and basic simulation concepts using Energy2D.

Hands on:

1. Heat conduction through different materials
2. Natural convection inside an enclosure Radiation heat transfer, Visualization of temperature contours, heat flux and velocity vectors

Case Study	Study the application of CFD simulations in aerospace, automotive, thermal systems, buildings and electronic cooling.

MODULE-2	**NUMERICAL DISCRETIZATION USING ENERGY2D**	**24MEE54.2**	**8 Hours**

Concepts of computational grids, numerical discretization, mesh resolution, stability and convergence through simulation-based learning using Energy2D. Energy2D Experiments -

Hands on:

1. Effect of mesh resolution on simulation accuracy
2. Heat transfer in materials with different thermal conductivities
3. Effect of insulated and non-insulated boundaries Steady-state and transient heat transfer
4. Influence of heat source location

Self-study	Analyze numerical accuracy and thermal behaviour of engineering materials under different boundary conditions.

MODULE-3	HEAT TRANSFER AND FLUID FLOW ANALYSIS USING ENERGY2D	24MEK63.3, 24MEK63.4	8 Hours
Finite Volume Method (FVM), control volume approach, discretization of diffusion equation, convection-diffusion equation, solution of algebraic equations, Tri-Diagonal Matrix algorithm.			
Hands on: 1. Comparative analysis of multiple simulation scenarios 2. Upwind and central difference schemes			
Self-study	Analyze numerical solutions of one-dimensional heat transfer and fluid flow problems.		
MODULE-4	**CFD ANALYSIS OF ENGINEERING SYSTEMS USING ENERGY2D**	**24MEK63.5**	**8 Hours**
Simulation of conduction, convection and combined heat transfer, visualization of temperature distribution and flow behaviour, and interpretation of numerical results.			
Hands on: 1. Natural convection inside cavities 2. Combined conduction and convection 3. Heat transfer in different enclosure geometries and effect of fluid properties on circulation 4. Comparative study of thermal performance.			
Self-study	Analyze heat transfer and fluid circulation in engineering systems using simulation results.		
MODULE-5	**SIMULATION, VISUALIZATION AND ENGINEERING APPLICATIONS USING ENERGY2D**	**24MEK63.6**	**8 Hours**
Simulation setup, visualization of temperature and flow fields, interpretation of numerical results, validation of simulations and engineering applications using Energy2D. Energy2D Experiments -			
Hands on: 1. Comparative study of insulation materials, 2. Thermal performance of multilayer walls, 3. Solar energy absorption under different surface conditions, 4. Cooling performance under varying environmental conditions			
Case Study	Interpret simulation results to evaluate and improve the thermal performance of engineering systems.		

CIE Assessment Pattern (50 Marks – Theory) –

RBT Levels		Marks Distribution		
		Test (s)	AAT1	AAT2
		25	15	10
L1	Remember	5	-	-
L2	Understand	5	5	-
L3	Apply	10	5	5
L4	Analyze	5	5	5
L5	Evaluate	-	-	-
L6	Create	-	-	-

SEE Assessment Pattern (50 Marks – Theory)

RBT Levels		Exam Marks Distribution (50)
L1	**Remember**	**10**
L2	**Understand**	**10**
L3	**Apply**	**20**
L4	**Analyze**	**10**
L5	**Evaluate**	**--**
L6	**Create**	**--**

Suggested Learning Resources:

Text Books

1. Jiyuan Tu, Guan Heng Yeoh and Chaoqun Liu, Computational Fluid Dynamics: A Practical Approach, 4th Edition, Butterworth-Heinemann, 2023, ISBN: 9780323958792.
2. H.K. Versteeg and W. Malalasekera, An Introduction to Computational Fluid Dynamics – The Finite Volume Method, 3rd Edition, Pearson, Reprint 2021, ISBN: 9780131274985.

Reference Books

1. John D. Anderson Jr., Computational Fluid Dynamics – The Basics with Applications, McGraw Hill, Reprint 2021, ISBN: 9781259025969.
2. T.J. Chung, Computational Fluid Dynamics, Cambridge University Press, Reprint 2021, ISBN: 9781108418495.
3. Suhas V. Patankar, Numerical Heat Transfer and Fluid Flow, CRC Press, Reprint 2021, ISBN: 9780891165226

Web links and Video Lectures (e-Resources):

- https://nptel.ac.in/courses/112107264
- https://nptel.ac.in/courses/112104030
- https://onlinecourses.nptel.ac.in
- https://www.openfoam.com
- https://www.ansys.com/academic

Activity-Based Learning (Suggested Activities in Class)/ Practical Based learning

- CFD simulation of flow through a circular pipe.
- Numerical solution of one-dimensional diffusion equation.
- Meshing and grid independence study using CFD software.
- CFD analysis of flow over an airfoil or bluff body.
- Comparative study of theoretical and CFD results for engineering flow problems.

RELIABILITY AND MAINTENANCE ENGINEERING

Course Code	**24MEE641**	**CIE Marks**	**50**
L:T:P:S	**3:0:0:0**	**SEE Marks**	**50**
Hrs / Week	**03**	**Total Marks**	**100**
Credits	**03**	**Exam Hours**	**03**

Course outcomes:

At the end of the course, the student will be able to:

24MEE641.1	Apply relevant design codes, basic principles, and metallurgical considerations for static equipment to ensure safety and overpressure protection.
24MEE641.2	Evaluate and select appropriate Non-Destructive Evaluation (NDE) techniques and industry standards (ASME, API, AWS) for flaw assessment and fitness-for-service evaluation.
24MEE641.3	Analyze static and rotating equipment criticality using Reliability Centered Maintenance (RCM) methodologies to formulate mitigation strategies and redesigns.
24MEE641.4	Model failure patterns, degradation profiles, and quantitative risk matrices to determine operational thresholds and probability of failure.
24MEE641.5	Formulate maintenance strategies, outage schedules, and inventory plans using modern digital tools.
24MEE641.6	Synthesize design, inspection, risk assessment, and scheduling practices to build an integrated asset integrity management strategy for industrial plants.

Mapping of Course Outcomes to Program Outcomes and Program Specific Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2
24MEE641.1	3	2	3	-	-	2	-	-	-	-	-	3	3
24MEE641.2	3	3	-	2	2	-	-	-	-	-	-	3	2
24MEE641.3	3	3	2		-	-	-	-	-	-	-	2	3
24MEE641.4	3	3	-	3	-	-	-	-	-	-	-	2	3
24MEE641.5	-	-	-	-	3	-	-	-	3	1	1	3	2
24MEE641.6	3	3	3	3	-	-	-	-	-	-	3	3	3

MODULE-1	**STATIC EQUIPMENT FAMILIARIZATION & SAFETY**	**24MEE641.1 24MEE641.6**	**8 Hours**

Design aspects of all the static equipment like Pressure vessels/ Columns/ Heat exchangers and its applications, Overview of design codes and basic principles - Section VIII Div 1 & 2/ ASME B31.3/ API 660/ TEMA, design for internal pressures/ external pressures and concept of load combinations/ allowable stresses and change in allowable owing to design temperatures, Safety relief and protection against over pressurization, Metallurgy / Fabrication techniques of welds, evaluation of welds and testing.

Case Study	Pressure vessel failure investigation due to over-pressurization, code compliance review (ASME Section VIII) and safety relief system evaluation in a petrochemical plant.
Text Book	Text Book 1: Chapters 1, 5, 6 and 18 , Text Book 2: Chapters 5, 6 and 11

MODULE-2	**NON-DESTRUCTIVE EVALUATION (NDEs) & APPLICATIONS**	**24MEE641.2**	**8 Hours**

Overview of Various NDEs - Radiography, Thermal inspection, Holography, Ultrasonic used for in-service inspection, a brief discussion on selecting the right technique for each component based on expected damage, Acceptance criteria and evaluation of results- Interpretation and characterization of defects, flaw assessment methodologies, defect acceptance and rejection criteria.

Overview and linkage of inspection practices with design and construction codes, Overview of ASME Boiler and Pressure Vessel Code (Sections V and VIII), API 510 for pressure vessels, API 570 for piping systems, API 579 Fitness-for-Service, AWS D1.1 welding standards.			
Self-study	NDE technique selection for high-pressure static vessel inspections and code compliance validation.		
Text Book	Text Book 1: 1.1, 1.2, 1.3, 1.6, 2.1, 2.2, 2.3, 4.1, 4.2, 4.3, 4.4, 4.5		
MODULE-3	**RELIABILITY OF STATIC AND ROTATING EQUIPMENT**	**24MEE641.3**	**8 Hours**
Equipment Criticality, Fundamentals of Reliability Centered Maintenance (RCM), Core RCM methodology- Function / Functional failure criteria / explicit Failure modes/ Failure effects / Failure Consequence / Application of Mitigation Strategies / Upgrade or engineering Redesign.			
Case Study	A comprehensive RCM framework for a multi-stage centrifugal pumping system.		
Text Book	Text Book 1: 5.1, 5.2, 5.3, 5.4, 5.5, 5.7, 5.8, 6.1, 6.2, 6.3, 6.4, 7.1, 7.3 Text Book 2: 5.1, 5.3, 5.6, 6.1		
MODULE-4	**FAILURE PATTERNS & RISK ASSESSMENT MECHANICS**	**24MEE641.4**	**8 Hours**
Comprehensive study of Failure patterns, Detailed modeling of the Bathtub curve / wear out - Age related degradation profiles and Random failures distribution frequencies, Quantitative Risk Matrix -plotting Consequence / Probaility of failure (PoF) to define operational thresholds.			
Case Study	Industrial Risk Matrix deployment within an active hydrocarbon processing plant facility.		
Text Book	Text Book 1: 9.1, 9.2, 9.3, 10.1, 10.2, 10.3 Text Book 2: 11.2, 11.2, 10.4, 10.5		
MODULE-5	**MAINTENANCE - PLANNING / SCHEDULING AND SHUT DOWN MANAGEMENT**	**24MEE641.5**	**8 Hours**
Static and rotating Equipment Strategy Development-Plan to reduce the risks- by providing predictive / preventive / annual maintenance plan / shut down plan, Planning and scheduling for outages (planned & unplanned)/ inventory planning - only concepts, Maintenance handbook overview of the concepts/ topics, Tools Awareness - SAP S4 / Hana & Primavera P6.			
Self-study	Execution management and inventory optimization during a major refinery shutdown.		
Text Book	Text Book 1: 18.1, 18.2, 18.5, 18.6, 18.8, 18.10 Text Book 2: 2.1, 2.2, 2.3, 2.4		

CIE Assessment Pattern (50 Marks – Theory)

RBT Levels		Marks Distribution		
		Test (s)	AAT1	AAT2
		25	15	10
L1	Remember	5	-	-
L2	Understand	5	5	-
L3	Apply	10	5	5
L4	Analyze	5	5	5
L5	Evaluate	-	-	-
L6	Create	-	-	-

SEE Assessment Pattern (50 Marks – Theory)

RBT Levels		Exam Marks Distribution (50)
L1	Remember	10
L2	Understand	10
L3	Apply	20
L4	Analyze	10
L5	Evaluate	--
L6	Create	--

Suggested Learning Resources:

Text Books:

1) Mishra R.C. and Pathak K., 'Maintenance Engineering and Management', 2nd edition, Prentice Hall India Learning Private Limited, 2012, ISBN: 9788120345737
2) Garg H.P., 'Industrial Maintenance', 3rd edition, S. Chand Publishing, New Delhi, 2010, ISBN: 9788121901680

Reference Books:

1)Mobley R. Keith, 'An Introduction to Predictive Maintenance', 2002, Elsevier Science, 2nd Edition, ISBN: 9780750675314
2) Bloch Heinz P. and Geitner Fred K., 'Practical Machinery Management for Process Plants: Volume 2: Machinery Failure Analysis and Troubleshooting', 4th edition, Gulf Professional Publishing, 2012, ISBN: 9780123860446
3) Edgar Bradley, Reliability Engineering: A Life Cycle Approach, 2nd Edition, CRC Press (Taylor & Francis), 2023, Print ISBN: 978-1032353371

Web links and Video Lectures (e-Resources)

- https://nptel.ac.in/courses/112105232
- https://www.reliabilityweb.com/articles/reliability-centered-maintenance-rcm
- https://www.sciencedirect.com/book/9780750675314/an-introduction-to-predictive-maintenance
- https://www.reliabilitylane.com
- https://reliabilityweb.com/

Activity-Based Learning (Suggested Activities in Class)/ Practical Based learning

- Industrial plant visit to a thermal power station or manufacturing unit focusing on live outage management and rotating machinery monitoring setups.
- Practical execution and demonstration of NDE kits (Ultrasonic flaw detectors, dye penetrant checks) in

active laboratory test cells.

- Interactive development of RCM Flowcharts and asset logic profiles by dividing student teams into small technical evaluation cohorts.
- Organizing structured group discussions regarding structural root causes behind historical catastrophic asset failures due to maintenance omission.
- Technical seminar presentations focused on state-of-the-art predictive technologies including continuous IoT multi-axis vibration monitors.

FRACTURE MECHANICS

Course Code	**24MEE642**	**CIE Marks**	**50**
L: T:P:S	**3:0:0:0**	**SEE Marks**	**50**
Hrs / Week	**3**	**Total Marks**	**100**
Credits	**03**	**Exam Hours**	**03**

Course outcomes:

At the end of the course, the student will be able to:

24MEE642.1	Understand the basic concepts of Fracture Mechanics in engineering design and manufacture for brittle and ductile materials.
24MEE642.2	Apply different modes of crack propagation to understand fracture behavior under plane stress and plane strain conditions.
24MEE642.3	Analyze the principles and applications of Linear Elastic Fracture Mechanics (LEFM) and Elastic Plastic Fracture Mechanics (EPFM) in engineering applications.
24MEE642.4	Design the different types of specimens for fatigue and fracture analysis.
24MEE642.5	Analyze CTOD values obtained through different fracture mechanics methods using engineering analysis software.
24MEE642.6	Apply different Non-Destructive Testing (NDT) techniques to detect and evaluate fractures, cracks, and flaws in engineering materials.

Mapping of Course Outcomes to Program Outcomes and Program Specific Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2
24MEE642.1	3	2	-	-	-	-	-	-	-	-	-	-	2
24MEE642.2	2	3	-	2	-	-	-	-	-	-	-	-	3
24MEE642.3	2	3	-	3	-	-	-	-	-	-	-	-	3
24MEE642.4	-	-	3	2	-	-	-	-	-	-	-	2	3
24MEE642.5	-	2	2	3	3	-	-	-	-	-	-	2	3
24MEE642.6	2	3	-	3	3	-	-	-	-	-	-	3	2

MODULE-1	**FRACTURE MECHANICS PRINCIPLES AND STRESS ANALYSIS FOR MEMBERS WITH CRACKS**	**24MEE642.1, 24MEE642.3, 24MEE642.6**	**8 Hours**

Fracture Mechanics Principles: Introduction, Mechanisms of Fracture, a crack in structure, the Griffith's criterion, modern design – strengths, stiffness and toughness. Stress intensity approach.

Stress Analysis for Members with Cracks: Linear elastic fracture mechanics, Crack tip stress and deformations, Relation between stress intensity factor and fracture toughness, Stress intensity-based solutions. Crack tip plastic zone estimation, Plane stress and plane strain concepts. Dugdale approach, Spectacular Failures- Discussion on Boston molasses failure, Liberty ship failure, Ductile-brittle transition temperature and its relevance

Self-study	Failure Analysis of a Cracked Aircraft Wing Panel and Railway Track Crack Analysis.
Text Book	Text Book 1: 1.2, 1.3, 1.4, 1.13, 1.15, 1.16

MODULE-2	**ELASTIC-PLASTIC FRACTURE MECHANICS**	**24MEE642.2, 24MEE642.5**	**8 Hours**

Elastic – Plastic Fracture Mechanics: Introduction, Elasto-plastic factor criteria, crack resistance curve, J-integral, Crack opening displacement, crack tip opening displacement. Importance of R- curve in fracture mechanics, the use of Crack Tip Opening Displacement (CTOD) criteria. Experimental determination of CTOD. Parameters affecting the critical CTOD.

Case Study	Fracture Analysis of Welded Joints in Structural Steel, Finite Element Analysis of Cracked Components.
Text Book	Text Book 1: 2.2, 2.3, 2.4 to 2.15

MODULE-3	**DYNAMIC AND CRACK ARREST, FATIGUE AND**	**24MEE642.2,**	**8 Hours**

	FATIGUE CRACK GROWTH RATE	**24MEE642.3**	
Dynamic And Crack Arrest: Introduction, the dynamic stress intensity and elastic energy release rate, crack branching, the principles of crack arrest, the dynamic fracture toughness. Comparison of crack growth and critical value of K by MTS and SED Fatigue and Fatigue Crack Growth Rate: Fatigue loading, various stages of crack propagation, the load spectrum, approximation of the stress spectrum, the crack growth integration, fatigue crack growth laws. Paris Law and Sigmoidal Curve, crack closer.			
Self-study	Dynamic Fracture Analysis of High-Speed Railway Axles, Failure Analysis of Crankshaft Due to Fatigue		
Text Book	Text Book 2: 3.1, 3.3, 3.5, 3.7, 3.10		
MODULE-4	**FRACTURE RESISTANCE OF MATERIALS**	**24MEE642.4, 24MEE642.6**	**8 Hours**
Fracture Resistance of Materials: Fracture criteria, fatigue cracking criteria, effect of alloying and second phase particles, effect of processing and anisotropy, effect of temperature, closure. Computational Fracture Mechanics: Overview of numerical methods, traditional methods in computational fracture mechanics – stress and displacement marching.			
Case Study	Fracture Resistance Evaluation of Structural Steel, Comparative Study of Mild Steel and High-Strength Steel		
Text Book	Text Book 1: 6.1, 6.3, 6.5, 6.7, Text Book 2: 10.1, 10.3, 10.5, 10.7		
MODULE-5	**AI-ENHANCED FRACTURE TOUGHNESS TESTING AND ANALYSIS OF METALS**	**24MEE642.4, 24MEE642.6**	**8 Hours**
Fracture toughness testing of metals, including specimen size requirements, test procedures, and the effects of temperature, loading rate, and plate thickness, with AI-assisted analysis of experimental data. Fracture testing in shear modes, fatigue testing, and AI-enabled non-destructive testing (NDT) for automated crack detection and defect classification. Introduction to NASGRO and AFGROW with AI-based fatigue crack growth prediction and remaining life estimation. Study of empirical fatigue crack growth models, crack initiation, intrusion, extrusion, and slip bands using AI-driven image processing and predictive analytics.			
Applications	Fracture Toughness Assessment of Welded Steel Joints, Fracture Toughness Analysis of Automotive Components Application.		
Text Book	Text Book 2: 12.1 to 12.10		

CIE Assessment Pattern (50 Marks – Theory) –

RBT Levels		Marks Distribution		
		Test (s)	AAT1	AAT2
		25	15	10
L1	Remember	5	-	-
L2	Understand	5	5	-
L3	Apply	10	5	5
L4	Analyze	5	5	5
L5	Evaluate	-	-	-
L6	Create	-	-	-

SEE Assessment Pattern (50 Marks – Theory)

RBT Levels		Exam Marks Distribution (50)
L1	Remember	10
L2	Understand	10
L3	Apply	20
L4	Analyze	10
L5	Evaluate	--
L6	Create	--

Suggested Learning Resources:

Text Books:

1. Introduction to fracture mechanics, Dietmar and Thomas seeling, 2026, ISBN-13: 978- 3319710891, ISBN-10: 3319710893

2.Fracture of Engineering Brittle Materials, Jayatilake, Applied Science, London. 2026, ISBN-13-978-3345457810.

Reference Books:

1.Fracture Mechanics – Fundamentals and Application, T.L. Anderson, CRC press ,4TH EDITION,2025, ISBN-13: 978-1498728133

2.Elementary Engineering Fracture Mechanics, David Broek, ArtinusNijhoff, London 2026, ISBN-13: 978-9024726561

3.Fracture and Fatigue Control in Structures, Rolfeand Barsom, Printice Hall 2025, ISBN- 13: 978-0133298635

Web links and Video Lectures (e-Resources):

- **https://youtu.be/G5mcTw-PLEI?si=wtNOqlLQVVbNDvi1**
- **https://youtu.be/G5mcTw-PLEI?si=VPCpjEE5cpE2-TvM**
- **https://youtu.be/G5mcTw-PLEI?si=qje3uQNEFKytS8eC**
- **https://youtu.be/G5mcTw-PLEI?si=QLXQ8v142g_jyG7I**
- **https://youtu.be/GfOPaztB8Xs?si=El-HFy-SyXfB6EdU**

Activity-Based Learning (Suggested Activities in Class)/ Practical Based learning

- Stress Concentration Demonstration.
- Charpy Impact Test Demonstration.
- Predict fatigue crack growth and component life.
- Use FEA tools for crack analysis.
- Apply fracture mechanics principles to real engineering failures.
- Calculate fracture mechanics parameters.
- Fracture Surface Examination.

DIGITAL TWIN TECHNOLOGY

Course Code	**24MEE643**	**CIE Marks**	**50**
L:T:P:S	**3:0:0:0**	**SEE Marks**	**50**
Hrs / Week	**3**	**Total Marks**	**100**
Credits	**03**	**Exam Hours**	**03**

Course outcomes:

At the end of the course, the student will be able to:

24MEE643.1	Understand the fundamental concepts, evolution, maturity models, and enabling technologies of Digital Twins.
24MEE643.2	Analyse physics-based, data-driven, and hybrid approaches for Digital Twin development and apply gap analysis methods.
24MEE643.3	Apply data types, analytics pipelines, and IoT-based data infrastructure in Digital Twin systems
24MEE643.4	Analyze real-time simulation, visualization techniques, and performance metrics relevant to Digital Twin deployments
24MEE643.5	Apply AI and ML techniques within Digital Twin frameworks to solve mechanical engineering problems and address challenges in scalability, security, and ethics.
24MEE643.6	Develop Digital Twin implementation strategies aligned with governance, ethical, societal, sustainability, and global frameworks such as the UN Sustainable Development Goals (SDGs)

Mapping of Course Outcomes to Program Outcomes and Program Specific Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2
24MEE643.1	3	1	-	-	2	-	-	-	-	-	2	-	1
24MEE643.2	2	3	2	2	2	-	-	-	-	-	2	-	3
24MEE643.3	2	2	-	2	3	-	-	-	-	-	2	-	2
24MEE643.4	2	2	2	3	3	-	-	-	-	-	2	-	2
24MEE643.5	2	3	3	2	3	1	1	-	-	-	2	1	3
24MEE643.6	-	2	1	-	-	3	3	-	-	-	2	-	1

MODULE-1	**FOUNDATIONS OF DIGITAL TWINS**	**24MEE643.1**	**8 Hours**

Definition and evolution of Digital Twins; Grieves' original concept and the NASA Digital Twin initiative; The three pillars: Physical entity, Virtual model, and Data connection; Distinction between Digital Twins, simulation models, CAD models, and BIM.

Digital Twin maturity levels (Levels 0-5); Enabling technologies overview: IoT, Cloud Computing, Edge Computing, Big Data, and Artificial Intelligence; Application domains: manufacturing, aerospace, structural health monitoring, smart cities, and healthcare; Digital Thread concept and its role in product lifecycle management.

Case Study	Analyse a real-world Digital Twin deployment (e.g., GE Digital Twin for jet engines or Siemens MindSphere) - identify the physical entity, virtual model, data connections, and maturity level.
Text Book	Text Book 1: Chapters 1; Text Book 2: Chapter 1

MODULE-2	**DIGITAL TWIN DEVELOPMENT APPROACHES**	**24MEE643.2**	**8 Hours**

Physics-based modelling: first-principles equations, finite element concepts, state-space representation; Data-driven approaches: regression models, time-series models, machine learning-based surrogates; Hybrid approaches: combining physics and data for improved accuracy; Business Process Model and Notation (BPMN) basics for process mapping; Gap analysis methodology: identifying process gaps and mapping Digital Twin solutions;

Self-study	Compare physics-based and data-driven Digital Twin approaches for a thermal system of your choice. Prepare a one-page summary of trade-offs in accuracy, cost, and data requirements.
Text Book	Text Book 1:Chapter 2

MODULE-3	DATA INFRASTRUCTURE AND ANALYTICS	24MEE643.3	8 Hours
Digital Twin data types: geometric, behavioural, historical, real-time, and synthetic; IoT sensor integration and data acquisition pipelines; Data storage technologies: time-series databases, cloud platforms (AWS IoT, Azure Digital Twins, ThingSpeak). Analytics hierarchy: descriptive, diagnostic, predictive, and prescriptive analytics; Data interoperability and standards: ISO 23247 for manufacturing Digital Twins; Digital Twin data security and privacy considerations.			
Applications	Explore the Azure Digital Twins free-tier or ThingSpeak platform. Connect a simulated sensor, visualise real-time data, and document the data pipeline from sensor to dashboard.		
Text Book	Text Book 1: Chapter 3		
MODULE-4	**SIMULATION, VISUALISATION AND REAL-TIME SYSTEMS**	**24MEE643.4**	**8 Hours**
Dynamic modelling and co-simulation principles; Feedback loops and control system integration in Digital Twins; Real-time synchronisation techniques; 3D visualisation: point clouds, mesh representations, digital scene graphs. Augmented Reality (AR) and Virtual Reality (VR) interfaces for Digital Twins; Multi-criteria evaluation for visualisation method selection; Performance metrics and KPIs: accuracy, latency, fidelity, scalability; Case study: real-time passenger flow Digital Twin at airports and smart manufacturing floors.			
Case Study	Evaluate three visualisation approaches (3D model, AR overlay, dashboard) for a manufacturing Digital Twin. Prepare a multi-criteria comparison matrix and justify the recommended approach.		
Text Book	Text Book 3: Chapter 1		
MODULE-5	**AI-DRIVEN DIGITAL TWINS AND GOVERNANCE**	**24MEE643.5, 24MEE643.6**	**8 Hours**
AI integration in Digital Twins: overview and motivation; ML for predictive maintenance: supervised learning, anomaly detection; Physics-Informed Neural Networks (PINNs): combining physical laws with neural network learning. Generative AI and LLMs for DT querying and report generation; Autonomous Digital Twins: self-calibrating and self-optimising systems; Scalability, interoperability, and security challenges in industrial DT deployments. Governance and ethics: ethical frameworks for AI-driven Digital Twins; bias and transparency in DT decision-making; data sovereignty and privacy regulations; Digital Twins and the UN Sustainable Development Goals (SDGs); future directions: autonomous DTs, edge-AI integration, and DT ecosystems.			
Applications	Survey: Research one published case study of an AI-driven Digital Twin in mechanical or civil engineering. Identify the ML technique used, the data pipeline, and any ethical or governance challenges reported.		
Text Book	Text Book 2: Chapter 3 and 4; Text Book 3: Chapter 3		

CIE Assessment Pattern (50 Marks – Theory) –

RBT Levels		Marks Distribution		
		Test (s)	AAT1	AAT2
		25	15	10
L1	Remember	5	-	-
L2	Understand	5	5	-
L3	Apply	10	5	5
L4	Analyze	5	5	5
L5	Evaluate	-	-	-
L6	Create	-	-	-

SEE Assessment Pattern (50 Marks – Theory)

RBT Levels		Exam Marks Distribution (50)
L1	**Remember**	**10**
L2	**Understand**	**10**
L3	**Apply**	**20**
L4	**Analyze**	**10**
L5	**Evaluate**	**--**
L6	**Create**	**--**

Suggested Learning Resources:

Text Books:

1. Soheil Sabri, Kostas Alexandridis, Newton Lee, "Digital Twin: Fundamentals and Applications", Publisher: Springer International Publishing AG, 2024, ISBN : 978-3031677779.
2. Gopal Chaudhary, Manju Khari, Mohamed Elhoseny, "Digital Twin Technology: Fundamentals and Applications", Publisher: CRC Press, 2022, ISBN: 9780367677978
3. Lavanya Sharma, Pradeep Kumar Garg, "Digital Twins and Simulation Technology Concepts and Applications", Publisher: Chapman & Hall, 2025, ISBN: 9781032949390

Reference Books:

1. Rob Foster, "Designing Digital Twins: A Problem-First Approach to Bridging the Real and Virtual Worlds", 2025, ISBN: 9781839219078.
2. Shyam Varan Nath, Peter Van Schalkwyk, Dan Issacs, "Building Industrial Digital Twins", Publisher: Packt Publishing, 2021, ISBN: 9781839219078.

Web links and Video Lectures (e-Resources):

- https://www.digitaltwinconsortium.org/
- nptel.ac.in/courses/127101872
- How "Digital Twins" Could Help Us Predict the Future | Karen Willcox | TED - YouTube
- Online Learning - Digital Twin Hub
- https://openmodelica.org/
- Cooja Simulator Code Projects | Cooja simulator for iot Download Tutorials | Network Simulation Tools

Activity-Based Learning (Suggested Activities in Class)/ Practical Based learning

- Case Study Analysis: Students analyse a real-world Digital Twin deployment and present a gap analysis report identifying data, model, and governance gaps.
- BPMN Mapping Exercise: Students draw business process models for a given engineering scenario and identify Digital Twin intervention points.
- Platform Exploration: Hands-on exploration of Azure Digital Twins or ThingSpeak for IoT data visualization.

REFRIGERATION AND AIR CONDITIONING

Course Code	**24MEE644**	**CIE Marks**	**50**
L:T:P:S	**3:0:0:0**	**SEE Marks**	**50**
Hrs / Week	**3**	**Total Marks**	**100**
Credits	**03**	**Exam Hours**	**03**

Course outcomes:

At the end of the course, the student will be able to:

24MEE644.1	Understand Basics of Refrigeration and AC (HVAC & R) thermodynamic cycles
24MEE644.2	Apply the principles of VCRS (various configurations) and VARS to explain their operation in industrial applications.
24MEE644.3	Analyze the selection criteria of refrigerants with respect to eco-friendly operation
24MEE644.4	Analyze various indoor and outdoor HVAC design conditions based on human comfort condition requirements and an overview of Data Centre cooling
24MEE644.5	Understand Concepts and working of various types of industrial/commercial ACs and Refrigeration systems along with basic idea of cooling load calculation
24MEE644.6	Differentiate various types ducting design of industrial ACs and Refrigeration systems based on applications

Mapping of Course Outcomes to Program Outcomes and Program Specific Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2
24MEE644.1	2	2	-	-	-	-	-	-	-	-	-	2	-
24MEE644.2	2	1	-	-	-	-	-	-	-	-	-	2	-
24MEE644.3	2	-	-	-	-	-	-	-	-	-	-	2	-
24MEE644.4	2	3	2	-	-	-	-	-	-	-	-	2	-
24MEE644.5	2	2	-	-	-	-	-	-	-	-	-	2	-
24MEE644.6	2	1	3	-	-	-	-	-	-	-	-	2	-

MODULE-1	**INTRODUCTION TO REFRIGERATION**	**24MEE644.1**	**8 Hours**

Introduction about Refrigeration – Definitions of various terms. Methods of refrigeration. Air refrigeration system. Bell – Coleman cycle. Introduction about Air craft Air-Conditioning. Simple numerical on the same.

Case Study	Bell-Coleman cycle used in aircraft cooling, compare its performance with vapour compression systems
Text Book	Text Book 1: 1.1, 1.2

MODULE-2	**VCRS & VARS SYSTEMS**	**24MEE644.2**	**8 Hours**

Analysis of Vapour compression cycle, Modifications to basic cycle. Multi pressure systems. Multi evaporator system and Cascade systems. Vapour Absorption Refrigeration System. Applications of VCRS & VARS. Simple numerical on VCRS & VARS.

Self-study	Multi-stage VCRS in a Dairy Processing Plant – Analyze the refrigeration system used for milk chilling
Text Book	Text Book 1: 2.1, 2.2, 2.3 Text Book 2: 3.2,3.3,3.4,7.2,7.3,7.4,7.5,7.6

MODULE-3	**REFRIGERANTS**	**24MEE644.3**	**8 Hours**

Pollution by refrigerants. Various Refrigerants selection and properties - overview. Use of solar energy, low grade energy to run the refrigeration system. Methods of refrigeration in Dry ice manufacturing, Ejector refrigeration system, Evaporative Coolers. Desiccant cooling system – overview (No Numerical)

Self-study	Compare R22, R410A, R32 and R290 in terms of ODP, GWP, energy efficiency, safety and environmental impact

Text Book	Text Book 1:3.1, 3.2 Text Book 2 : 8.1,8.3,8.4,8.11,8.12		
MODULE-4	**PSYCHROMETRY**	**24MEE644.4**	**8 Hours**
Psychrometry – Definitions for properties. Introduction to AC cooling load calculations. Comfort conditions. Data Center Cooling. Effective temperature and humidity (ADP) concept. Idea of cooling load calculation Freeware's. Simple numerical (with & without using psychrometric chart)			
Case Study	HVAC Design for a Data Centre – Evaluate indoor comfort parameters, psychrometric processes and cooling load estimation for maintaining server room temperature and humidity.		
Text Book	Text Book 1:4.1, 4.2 Text Book 2: 17.1,17.2,17.3,17.4		
MODULE-5	**APPLICATIONS OF AIR CONDITIONING & REFRIGERATION SYSTEMS**	**24MEE644.5 24MEE644.6**	**8 Hours**
Air-conditioning systems – discussion about the central plant with direct evaporator and chiller applications, Ice plant, refrigerators. Duct sizing methods. Simple numerical. Idea of Duct Sizing Freeware's. Food preservation, IQF technique and freeze drying etc. Cold storage and thermal insulation. Simple numerical. Chiller optimization using data driven methods.			
Case Study	Cold Storage for Fruits and Vegetables – Study refrigeration load, insulation, duct sizing and temperature control methods.		
Text Book	Text Book -1: 5.1, 5.2		

CIE Assessment Pattern (50 Marks – Theory) –

RBT Levels		Marks Distribution		
		Test (s)	AAT1	AAT2
		25	15	10
L1	Remember	5	-	-
L2	Understand	5	5	-
L3	Apply	10	5	5
L4	Analyze	5	5	5
L5	Evaluate	-	-	-
L6	Create	-	-	-

SEE Assessment Pattern (50 Marks – Theory)

RBT Levels		Exam Marks Distribution (50)
L1	Remember	10
L2	Understand	10
L3	Apply	20
L4	Analyze	10
L5	Evaluate	--
L6	Create	--

Suggested Learning Resources:

Text Books:

1) C.P. Arora, Refrigeration and Air Conditioning, Publisher - TMH, 4th Edition, 2021, ISBN-10 9390385849, ISBN-13 978-9390385843

2) R.C. Arora, Refrigeration and Air Conditioning, Publisher – 2010, PHI, ISBN-10 9788120339156, ISBN-13 978-8120339156

Reference Books:

1) ASHRAE Handbook - Fundamentals, Publisher – ASHRAE, 2017, ISBN-10 1947192892, ISBN-13 978-1947192898
2) CIBSE Guide B – Heating , Ventilating ,air Conditioning and Refrigeration, Publisher-CIBSE 2nd Edition, May 2005, ISBN-1 903287 58 8

Web links and Video Lectures (e-Resources):

- https://onlinecourses.nptel.ac.in/e-learning/preview/noc19_me58
- https://comfort.cbe.berkeley.edu/
- NPTEL :: Mechanical Engineering - Refrigeration and Air Conditioning
- https://reftools.danfoss.com/spa/tools#/

Activity-Based Learning (Suggested Activities in Class)/ Practical Based learning

- Demonstrate the working of a domestic refrigerator and identify the major components and refrigerant flow path.
- Perform psychrometric calculations using a psychrometric chart or HVAC software for different indoor comfort conditions.
- Conduct an energy audit of classroom/college air-conditioning systems and suggest methods to improve COP and reduce power consumption.
- Prepare a comparative study of conventional and eco-friendly refrigerants based on ASHRAE safety classification, ODP and GWP.
- Visit a cold storage plant, supermarket refrigeration unit or central air-conditioning plant and submit a technical report on system components and operation.

NON TRADITIONAL MACHINING			
Course Code	**24MEE645**	**CIE Marks**	**50**
L:T:P:S	**3:0:0:0**	**SEE Marks**	**50**
Hrs / Week	**03**	**Total Marks**	**100**
Credits	**03**	**Exam Hours**	**03**

Course outcomes:

At the end of the course, the student will be able to:

24MEE645.1	Identify the uses of Non-traditional machines for modern manufacturing industries.
24MEE645.2	Understand the uses of Ultrasonic, Water jet & Abrasive jet Machining process.
24MEE645.3	Analyze the methods of Chemical and Electrochemical non- traditional machining.
24MEE645.4	Analyze the process of Electrical Discharge and Ion beam machining
24MEE645.5	Develop the suitable applications of Plasma arc, Electron beam and laser beam machining for NTM
24MEE645.6	Apply the Hybrid Machining and modern finishing process in NTM.

Mapping of Course Outcomes to Program Outcomes and Program Specific Outcomes:

	PO1	PO 2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2
24MEE645.1	2	2	-	-	-	-	-	-	-	-	-	2	-
24MEE645.2	2	2	-	-	-	-	-	-	-	-	-	2	-
24MEE645.3	3	2	-	-	-	-	-	-	-	-	-	2	-
24MEE645.4	3	3	-	-	-	-	-	-	-	-	-	2	-
24MEE645.5	3	2	-	-	-	-	-	-	-	-	-	2	-
24MEE645.6	3	3	-	-	-	-	-	-	-	-	-	2	-

MODULE-1	**INTRODUCTION, ULTRASONIC, WATER JET, ABRASIVE JET MACHINING**	**24MEE645.1 24MEE645.2**	**8 Hours**

Need for Non-traditional machining process, comparison between traditional and non-traditional machining, classification of Nontraditional machining processes, Specific advantages, limitations and applications of non-traditional machining processes.

Introduction, Equipment and process of material removal for USM, WJM, AJM

Ultrasonic Machining (USM): Effect of process parameters: Effect of amplitude and frequency, Effect of abrasive grain diameter, effect of slurry, tool & work material. Process characteristics: Material removal rate, tool wear, accuracy, surface finish, applications, advantages & limitations of USM.

Water Jet Machining (WJM), Abrasive Jet Machining (AJM): process variables: carrier gas, type of abrasive, work material, stand-off distance (SOD). Process characteristics-Material removal rate, Nozzle wear, accuracy & surface finish. Applications, advantages & limitations of WJM and AJM.

Self-Study/Case Study	Study about nontraditional machining, USM/AJM related
Text Book	Text Book 1: Ch. 1, 2

MODULE-2	**ELECTROCHEMICAL AND CHEMICAL MACHINING**	**24MEE645.3**	**8 Hours**

Electrochemical Machining (ECM): Introduction, Principle of electro chemical machining, ECM, elements of ECM operation, Chemistry of ECM. ECM Process characteristics: Material removal rate, accuracy, surface finish. Process parameters: Current density, Tool feed rate, Gap between tool & work piece, velocity of electrolyte flow, type of electrolyte, its concentration temperature, and choice of electrolytes. ECM Tooling: ECM tooling technique & example, Tool & insulation materials. Applications ECM: Electrochemical grinding, deburring and electrochemical honing process. Advantages, disadvantages and application of ECG, ECH.

Chemical Machining (CHM): Elements of the process, Resists (maskants), Etchants. Types of chemical machining process-chemical blanking process, chemical milling process. Process characteristics of CHM: material removal rate, accuracy, surface finish, advantages, limitations and applications of chemical machining process.			
Self-study	Study the ECM/CHM		
Text Book	Text Book 3 Ch.3,4,5		
MODULE-3	**ELECTRICAL DISCHARGE AND ION BEAM MACHINING**	**24MEE645.4**	**8 Hours**
Electrical Discharge Machining (EDM): Introduction, mechanism of metal removal, EDM equipment: spark erosion generator (relaxation type), dielectric medium-its functions & desirable properties, electrode feed control system. Flushing types; pressure flushing, suction flushing, side flushing, pulsed flushing. EDM process parameters: Spark frequency, current & spark gap, surface finish, Heat Affected Zone. Advantages, limitations & applications of EDM, Electrical discharge grinding, Traveling wire EDM. Ion Beam Machining (IBM): Introduction, Principle, equipment and mechanism of metal removal, applications, advantages and limitations.			
Applications	Study the applications of EDM/IBM		
Text Book	Text Book 2: Ch. 3-4,5 Text Book 3: Ch. 4-5,6		
MODULE-4	**PLASMA ARC, LASER BEAM, ELECTRON BEAM MACHINING PROCESSES**	**24MEE645.5**	**8 Hours**
Plasma Arc Machining (PAM): Introduction, non-thermal generation of plasma, equipment mechanism of metal removal, Plasma torch, process parameters, process characteristics. Safety precautions. Safety precautions, applications, advantages and limitations. Laser Beam Machining (LBM): Introduction, generation of LASER, Equipment and mechanism of metal removal, LBM parameters and characteristics, Applications, Advantages & limitations. Electron Beam Machining (EBM): Introduction, Principle, equipment and mechanism of metal removal			
Self-Study	Study the process of PAM, LBM, EBM		
Text Book	Text Book 2: Ch. 3-8,9 Text Book 3: Ch. 4-7,8		
MODULE-5	**HYBRID MACHINING AND NANO FINISHING**	**24MEE645.6**	**8 Hours**
Hybrid machining: Introduction - Various hybrid non-traditional machining processes, their working principles, equipments, effect of process parameters, applications, advantages and limitations. Selection and comparison of different non- traditional machining processes Nano Finishing: Principles, equipments, effect of process parameters, applications, advantages and limitations of Abrasive flow machining – Chemo mechanical polishing, Magnetic abrasive finishing, Magnetorheological finishing, Magneto rheological abrasive flow finishing, Application of AI in Nano finishing.			
Applications	Study the applications of Hybrid Machining and Nano finishing		
Text Book	Text Book 4: Ch.1,2 Text Book 5: Ch 4,5		

CIE Assessment Pattern (50 Marks – Theory)

RBT Levels		Marks Distribution		
		Test (s)	AAT1	AAT2
		25	15	10
L1	Remember	5	-	-
L2	Understand	5	5	-
L3	Apply	10	5	5
L4	Analyze	5	5	5
L5	Evaluate	-	-	-
L6	Create	-	-	-

SEE Assessment Pattern (50 Marks – Theory)

RBT Levels		Exam Marks Distribution (50)
L1	Remember	10
L2	Understand	10
L3	Apply	20
L4	Analyze	10
L5	Evaluate	--
L6	Create	--

Suggested Learning Resources:

Text Books:

1) P.C Pandey and H S Shah, "Modern Machining Process", Mc Graw Hill Education India Pvt. Ltd. 2020, ISBN-13: 978-0070965539
2) Adithan. M., "Unconventional Machining Processes", Atlantic, New Delhi, India, 2019, ISBN 13: 978-8126910458.
3) Anand Pandey, "Modern Machining Processes", Ane Books Pvt. Ltd., New Delhi, India, 2018, ISBN-13: 978-9386761835
4) Kapil Gupta, Neelesh K. Jain and Laubscher R.F., "Hybrid Machining Processes: Perspectives on Machining and Finishing", 1st edition, Springer International Publishing., Switzerland, 2016, ISBN13: 978-3319259208
5) Golam Kibria, Bhattacharyya B. and Paulo Davim J., "Non-traditional Micromachining Processes: Fundamentals and Applications", Springer International Publishing., Switzerland, 2017, ISBN-13: 978-3- 319-52008-7

Reference Books:

1) Benedict, G.F., "Non-traditional Manufacturing Processes", Marcel Dekker Inc., New York 2017, ISBN-13: 978-0824773526.
2) Carl Sommer, "Non-Traditional Machining Handbook", Advance Publishing., United States, 2018, ISBN-13: 978-1575373256.
3) Jagadeesha T., "Non-Traditional Machining Processes", I.K. International Publishing House Pvt. Ltd., New Delhi, India, 2017, ISBN-13: 978-9385909122.

Web links and Video Lectures (e-Resources):

- https://in.video.search.yahoo.com/yhs/search?fr=yhs-sz-002&ei=UTF-8&hsimp=yhs-002&hspart=sz&param1=2486481154&p=non+traditional+machining+video+links+youtube&vm=r&type=type80160-848365615#id=0&vid=059506308eba0918daad1037ea08844a&action=click
- https://in.video.search.yahoo.com/yhs/search?fr=yhs-sz-002&ei=UTF-8&hsimp=yhs-002&hspart=sz&param1=2486481154&p=non+traditional+machining+video+links+youtube
- https://in.video.search.yahoo.com/yhs/search?fr=yhs-sz-002&ei=UTF-8&hsimp=yhs-002&hspart=sz&param1=2486481154&p=non+traditional+machining+video+links+youtube

Activity-Based Learning (Suggested Activities in Class)/ Practical Based learning

- Visit the manufacturing Industry and study about the usage of modern machines.
- Visit any industrial exhibition centre and know about the modern machines.
- Convert any manufacturing operated machines into CNC machines by developing codes or use of AI code.

PYTHON PROGRAMMING FOR MECHANICAL APPLICATIONS

Course Code	**24MEE651**	**CIE Marks**	**50**
L:T:P:S	**0:0:1:0**	**SEE Marks**	**50**
Hrs / Week	**2**	**Total Marks**	**100**
Credits	**01**	**Exam Hours**	**03**

Course outcomes:
At the end of the course, the student will be able to:

24MEE651.1	Develop Python programs using fundamental programming constructs, data structures, functions, file handling and NumPy for engineering computations.
24MEE651.2	Apply numerical methods such as root-finding, differentiation, integration and ordinary differential equations using SciPy to solve engineering mathematics problems.
24MEE651.3	Analyse mechanical engineering systems involving heat transfer and vibrations using Python and visualize results using Matplotlib.
24MEE651.4	Analyse experimental engineering datasets using Pandas and develop basic machine learning models for prediction and fault classification.

Mapping of Course Outcomes to Program Outcomes and Program Specific Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2
24MEE651.1	3	2	-	-	3	-	-	-	-	-	-	-	-
24MEE651.2	3	3	2	-	-	-	-	-	-	-	-	-	3
24MEE651.3	3	2	-	-	-	-	-	-	-	-	-	3	3
24MEE651.4	2	3	-	-	3	-	-	-	-	-	-	2	3

Pgm. No.	List of Programs	Hours	COs
	Prerequisite Programs		
	• Familiarity with languages like C and C++ • Execution of different data types, operators and simple programs using C and C++ • Mechanics of materials and Heat transfer concepts	2	NA
	PART-A		
1.	Engineering Problem Solving using Loops and Conditional Statements	2	24MEE651.1
2.	Material Property Management using Lists, Dictionaries and Functions	2	24MEE651.1
3.	Experimental Data Processing using File Handling	2	24MEE651.2
4.	Matrix Operations and Solution of Linear Equation Systems	2	24MEE651.2
5.	Solution of Nonlinear Engineering Equations using Root-Finding Methods	2	24MEE651.2
6.	Computation of Velocity, Acceleration and Work Done using Numerical Methods	2	24MEE651.2
	PART-B		
7.	Transient Cooling Analysis of Engineering Systems	2	24MEE651.3
8.	Analysis of Heat Conduction through Composite Walls	2	24MEE651.3
9.	Simulation of Single Degree-of-Freedom Vibration Systems	2	24MEE651.3

10.	Visualization of Mechanical Engineering Experimental Data	2	24MEE651.4
11.	Statistical Analysis and Regression of Experimental Data	2	24MEE651.4
12.	Prediction of Engineering Parameters and Fault Classification using Machine Learning	2	24MEE651.4

PART-C

Beyond Syllabus Virtual Lab Content

(To be done during Lab but not to be included for CIE or SEE)

- **Classes and Objects**
  https://python-iitk.vlabs.ac.in/exp/classes-and-objects/
- **Constructors and Inheritance**
  https://python-iitk.vlabs.ac.in/exp/constructors-and-inheritance/
- **File Operators**
  https://python-iitk.vlabs.ac.in/exp/file-operators/

CIE Assessment Pattern (50 Marks – Lab)

RBT Levels		Test (s)	Weekly Assessment
		20	30
L1	Remember	-	-
L2	Understand	-	10
L3	Apply	10	10
L4	Analyze	10	10
L5	Evaluate	-	-
L6	Create	-	-

SEE Assessment Pattern (50 Marks – Lab)

RBT Levels		Exam Marks Distribution (50)
L1	Remember	05
L2	Understand	05
L3	Apply	20
L4	Analyze	20
L5	Evaluate	-
L6	Create	-

Suggested Learning Resources:

Reference Books:

1)Yuli Vasiliev , "Python for Data Science", Publisher: No Starch Press, 2022, ISBN: 9781718502208

2) Eric Matthes, "Python Crash Course", Third Edition, Publisher: No Starch Press, 2025, ISBN: 9781718502703

INTRODUCTION TO AUGMENT AND VIRTUAL REALITY

Course Code	**24MEE652**	**CIE Marks**	**50**
L:T:P:S	**0:0:1:0**	**SEE Marks**	**50**
Hrs / Week	**2**	**Total Marks**	**100**
Credits	**01**	**Exam Hours**	**03**

Course outcomes:

At the end of the course, the student will be able to:

24MEE652.1	Understand digital product creation technology and platform technology for VR and AR experiences
24MEE652.2	Apply controls for virtual object interactions and object instantiation techniques in gaming applications.
24MEE652.3	Analyze controls for virtual object interactions and object instantiation techniques used in gaming applications
24MEE652.4	Develop an interactive gaming app using available assets.

Mapping of Course Outcomes to Program Outcomes and Program Specific Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2
24MEE652.1	3	-	-	-	3	-	-	-	-	-	-	2	3
24MEE652.2	3	3	-	-	3	-	-	-	-	-	-	2	3
24MEE652.3	3	3	3	-	3	-	-	-	3	-	-	-	3
24MEE652.4	3	3	3	-	3	-	-	-	3	-	-	-	3

Pgm. No.	List of Programs	Hours	COs
	Prerequisite Programs		
	Proficiency in programming languages like C# or C++, Knowledge of 3D graphics	2	NA
	PART-A		
1.	Build a Metaverse Avatar: Create your own Metaverse avatars using Metaverse platforms like Roblox or VR Chat. Also customize their avatars' appearance and experiment with different virtual identities.	2	24MEE652.1
2.	Virtual World Exploration: Explore a Metaverse platform of your choice. Document the experiences, noting features, interactions, and any challenges which are encountered.	2	24MEE652.1
3.	Get started with Unity: Install and configure your development environment. Craft and customize sprites for your game's visual elements.	2	24MEE652.1
4.	Manage and optimize internal game assets efficiently. Control the game flow by saving and loading scenes seamlessly	2	24MEE652.2
5.	Generate a character featuring Rigid Body and Collider components. Develop a script for nuanced control over acceleration, deceleration, and character movement.	2	24MEE652.2
6.	Utilize ray casting to establish grounded status, permitting jumps exclusively when the character is on solid ground. Incorporate customizable parameters for jump height, movement speed, and more	2	24MEE652.2

PART-B			
7.	Craft a game object, tailor its attributes, and enhance it with various components. Craft a script that spawns a game object precisely at the mouse click location.	2	24MEE652.3
8.	Develop a coroutine for a gradual, time-based transformation of a game object's color.	2	24MEE652.3
9.	Construct a script deliberately containing errors (e.g., attempting to access a non-existent component) to explore error message outputs in the console	2	24MEE652.3
10.	Create a Canvas object by right-clicking in the Hierarchy and selecting "UI" > "Canvas," then configure its Render Mode to "Screen Space - Overlay.	2	24MEE652.4
11.	Craft a straightforward material for an object within the scene, such as a sphere, and experiment with various shader options, including properties like color, emission, and transparency.	2	24MEE652.4
12.	Access the Unity Asset Store through Unity's Window menu, and explore available free or trial assets that can enhance your scene, such as UI elements, shaders, particle effects, or 3D models.	2	24MEE652.4

PART-C

Beyond Syllabus Virtual Lab Content

(To be done during Lab but not to be included for CIE or SEE)

- **VR – Unity Learn**
  https://learn.unity.com/course/create-with-vr
- **Virtual Reality – LNCC**
  https://www.lncc.br/~jauvane/papers/RelatorioTecnicoLNCC-0603
- **Automation and Virtual Reality**
  https://mv-iitkgp.vlabs.ac.in/List%20of%20experiments.html

CIE Assessment Pattern (50 Marks – Lab)

RBT Levels		Test (s)	Weekly Assessment
		20	30
L1	Remember	-	-
L2	Understand	-	10
L3	Apply	10	10
L4	Analyze	10	10
L5	Evaluate	-	-
L6	Create	-	-

SEE Assessment Pattern (50 Marks – Lab)

RBT Levels		Exam Marks Distribution (50)
L1	Remember	05
L2	Understand	05
L3	Apply	20
L4	Analyze	20
L5	Evaluate	-
L6	Create	-

Suggested Learning Resources:

Reference Books:

1) Unity in Action: Multiplatform Game Development in C#, By Joe Hocking, Manning Publications, 2026, ISBN: 978-1617292323.
2) Unity Animation Essentials by Alan Thorn, Packt Publishers, 2025, ISBN: 978-1782174813.
3)Unity Artificial Intelligence Programming" by Dr. Davide Aversa, Packt, 2026, ISBN: 9781803238531.

GENERATIVE AI

Course Code	**24MEE653**	**CIE Marks**	**50**
L:T:P:S	**0:0:1:0**	**SEE Marks**	**50**
Hrs / Week	**2**	**Total Marks**	**100**
Credits	**01**	**Exam Hours**	**03**

Course outcomes:
At the end of the course, the student will be able to:

24MEE653.1	Apply generative AI tools and large language model APIs in Python for engineering documentation, code assistance and design queries.
24MEE653.2	Analyze topology optimization problems for the design of lightweight mechanical components using Python-based optimization libraries
24MEE653.3	Illustrate generative design workflows to explore multiple design alternatives for a component under specified loads and constraints.
24MEE653.4	Analyze AI-generated design outputs against engineering and manufacturability constraints, and document the design rationale.

Mapping of Course Outcomes to Program Outcomes and Program Specific Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2
24MEE653.1	2	2	-	-	3	-	-	-	-	-	-	2	
24MEE653.2	3	3	2	-	-	-	-	-	-	-	-	3	2
24MEE653.3	3	2	3	-	2	-	-	-	-	-	-	2	3
24MEE653.4	2	3	-	2	2	-	-	-	-	-	-	3	2

Pgm. No.	List of Programs	Hours	COs
	Prerequisite Programs		
	• Familiarization with C programming and Artificial Intelligence topics like LLMs • Knowledge of CAM-D and mechanics of materials	2	NA
	PART-A		
1	Engineering Problem Solving using Python Loops and Conditional Statements	2	24MEE653.1
2	Prompt-Based Generation and Debugging of Python Scripts for Engineering Calculations	2	24MEE653.1
3	Building a Retrieval-Based Question-Answering Tool over a Machine Design Handbook Excerpt	2	24MEE653.1
4	Formulating a Compliance Minimization Problem for a 2D Cantilever using the SIMP Method	2	24MEE653.2
5	Topology Optimization of a Bracket under Point Load using a Python Optimization Library	2	24MEE653.2
6	Effect of Volume Fraction and Filter Radius on Topology-Optimized Design Outcomes	2	24MEE653.2
	PART-B		
7	Generative Design Exploration of a Mounting Bracket under Multiple Load Cases using Fusion 360	2	24MEE653.3
8	Comparing Generative Design Alternatives for Weight Reduction of an	2	24MEE653.3

	Automotive Component		
9	Lattice Structure Generation for Additive Manufacturing using Generative Design Tools	2	24MEE653.3
10	Introduction to GAN-Based Surrogate Models for Rapid Topology Prediction	2	24MEE653.3
11	Manufacturability and Constraint Checking of an AI-Generated Design against Machining/3D-Printing Limits	2	24MEE653.4
12	Mini-Project: End-to-End Generative Design of a Lightweight Component with Documented Design Rationale	2	24MEE653.4

PART-C

Beyond Syllabus Virtual Lab Content

(To be done during Lab but not to be included for CIE or SEE)

- **Autodesk Fusion for Education**
  https://www.autodesk.com/products/fusion-360/students-teachers-educators
- **ANSYS Online Learning**
  https://courses.ansys.com/
- **ChatGPT OpenAI Playground**
- **https://platform.openai.com/login?next=%2Fchat%2Fedit**

CIE Assessment Pattern (50 Marks – Lab)

RBT Levels		Test (s)	Weekly Assessment
		20	30
L1	Remember	-	-
L2	Understand	-	10
L3	Apply	10	10
L4	Analyze	10	10
L5	Evaluate	-	-
L6	Create	-	-

SEE Assessment Pattern (50 Marks – Lab)

RBT Levels		Exam Marks Distribution (50)
L1	Remember	05
L2	Understand	05
L3	Apply	20
L4	Analyze	20
L5	Evaluate	-
L6	Create	-

Suggested Learning Resources:

Reference Books:

1) Niels Aage and Boyan S. Lazarov, "TopOpt in Python: An Educational Approach" (course notes and open-source TopOpt codes), Technical University of Denmark, 2021, ISBN: 978-94-007-0510-4

2) Krish, "Generative Design: A Paradigm for Design Research" in Design Computing and Cognition, Publisher: Springer, 2011, ISBN: 978-94-007-0509-8

R PROGRAMMING

Course Code	**24MEE654**	**CIE Marks**	**50**
L:T:P:S	**0:0:1:0**	**SEE Marks**	**50**
Hrs / Week	**2**	**Total Marks**	**100**
Credits	**01**	**Exam Hours**	**03**

Course outcomes:

At the end of the course, the student will be able to:

24MEE654.1	Understand R Data types for developing programs
24MEE654.2	Apply the different R Data Structures
24MEE654.3	Develop programming logic using R Packages
24MEE654.4	Analyze the data sets using R programming capabilities

Mapping of Course Outcomes to Program Outcomes and Program Specific Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2
24MEE654.1	1	2	-	-	-	-	-	-	-	-	-	-	-
24MEE654.2	1	1	2	-	-	-	-	-	-	-	-	1	-
24MEE654.3	1	1	2	-	-	-	-	-	-	-	-	1	1
24MEE654.4	1	2	3	-	-	-	-	-	-	-	-	2	2

Pgm. No.	List of Programs	Hours	COs
	Prerequisite Programs		
	• C-Programming and Statistics	2	NA
	PART-A		
1	Implement R-Loops with different examples.	2	24MEE654.1
2	Learn the basics of functions in R and implement with examples	2	24MEE654.1
3	Implement data frames in R. Write a program to join columns and rows in a data frame using c bind () and r bind () in R.	2	24MEE654.1
4	Implement different String Manipulation functions in R.	2	24MEE654.1
5	Implement different data structures in R(Vectors ,Lists ,Data Frames)	2	24MEE654.2
6	Write a program to read acsv file and analyze the data in the file in R	2	24MEE654.2
	PART-B		
7	Create pie charts and bar charts using R	2	24MEE654.2
8	Create a data set and do statistical analysis on the data using R	2	24MEE654.2
9	R program to find Correlation and Covariance	2	24MEE654.3
10	R program for Regression Modeling	2	24MEE654.3
11	R program to build classification model using KNN algorithm	2	24MEE654.4
12	R program to build clustering model using K-mean algorithm	2	24MEE654.4

PART-C

Beyond Syllabus Virtual Lab Content

(To be done during Lab but not to be included for CIE or SEE)

- **Introduction to R Programming**
  https://www.youtube.com/watch?v=nPmQPAh8XZY
- **Learn the basics of functions in R and implement with examples**
  https://www.youtube.com/watch?v=P9mDVhJrmg4
- **Implement R-Loops with different examples**
  https://www.youtube.com/watch?v=GMNTrVdYt1Q

CIE Assessment Pattern (50 Marks – Lab)

RBT Levels		Test (s)	Weekly Assessment
		20	30
L1	Remember	-	-
L2	Understand	-	10
L3	Apply	10	10
L4	Analyze	10	10
L5	Evaluate	-	-
L6	Create	-	-

SEE Assessment Pattern (50 Marks – Lab)

RBT Levels		Exam Marks Distribution (50)
L1	Remember	05
L2	Understand	05
L3	Apply	20
L4	Analyze	20
L5	Evaluate	-
L6	Create	-

Suggested Learning Resources:

Reference Books:

1. Roger D Peng, "R Programming for Data Science", Lean Publication, 2016, ISBN-13: 978-1365056826
2. Hadley Wickham, "R for Data Science: Import, Tidy, Transform, Visualize, and Model Data", Hadley Wickham, O'RELLY, 2017, ISBN-13: 978-9352134977
3. Garrett Goleman, "Hands-On Programming with R: Write Your Own Functions and Simulations", O'RELLY, 2019, http://cran.r-project.org(link is external), ISBN-13: 978-1-118-87936-8

DEEP LEARNING

Course Code	**24MEE655**	**CIE Marks**	**50**
L:T:P:S	**0:0:1:0**	**SEE Marks**	**50**
Hrs / Week	**2**	**Total Marks**	**100**
Credits	**01**	**Exam Hours**	**03**

Course outcomes:
At the end of the course, the student will be able to:

24MEE655.1	Apply feedforward and convolutional neural networks in Python using Keras/TensorFlow to solve engineering problems.
24MEE655.2	Analyze mechanical engineering sensor and image datasets using deep learning models for regression and classification tasks.
24MEE655.3	Develop convolutional neural network models for visual defect detection and condition monitoring of mechanical components.
24MEE655.4	Analyze deep learning model performance using validation metrics, and deploy a trained model as a predictive tool for an engineering application.

Mapping of Course Outcomes to Program Outcomes and Program Specific Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2
24MEE655.1	3	2	-	-	3	-	-	-	-	-	-	3	-
24MEE655.2	3	3	2	-		-	-	-	-	-	-	3	2
24MEE655.3	3	2	2	-	2	-	-	-	-	-	-	2	3
24MEE655.4	2	3	-	2	2	-	-	-	-	-	-	3	2

Pgm. No.	List of Programs	Hours	COs
	Prerequisite		
	• Knowledge of basic programming concepts using C. • Basic understanding of engineering mathematics and statistics. • Familiarity with mechanical engineering measurements and sensor data.	2	NA
	PART-A		
1	Prepare and normalize an engineering sensor dataset for neural network training.	2	24MEE655.1
2	Design and develop a single-layer perceptron model for binary classification of machine fault data.	2	24MEE655.1
3	Design and implement a multilayer feedforward neural network for regression of engineering parameters.	2	24MEE655.1
4	Analyze the effect of different activation functions and learning rates on neural network training convergence.	2	24MEE655.1
5	Develop a deep neural network regression model for prediction of tool wear or chiller power.	2	24MEE655.2
6	Develop and evaluate a deep neural network for classification of bearing fault conditions using vibration signal features.	2	24MEE655.2
	PART-B		
7	Implement and demonstrate convolution and pooling operations	2	24MEE655.3

	using a convolutional neural network for engineering image processing.		
8	Design and develop a convolutional neural network for surface defect classification of manufactured components.	2	24MEE655.3
9	Implement transfer learning using a pretrained convolutional neural network for mechanical component image classification.	2	24MEE655.3
10	Develop and evaluate a recurrent neural network (LSTM) for time-series forecasting of machine sensor data.	2	24MEE655.3
11	Analyze the performance of a trained deep learning classifier using confusion matrix, precision-recall, and ROC analysis.	2	24MEE655.4
12	Deploy a trained deep learning model as a predictive tool for an engineering application.	2	24MEE655.4

PART-C
Beyond Syllabus Virtual Lab Content
(To be done during Lab but not to be included for CIE or SEE)

- **Tensor Flow Tutorials**
  https://www.tensorflow.org/tutorials
- **Google Collab Introduction**
  https://colab.research.google.com/
- **Transformers in Vision**
  https://dp-dei.vlabs.ac.in/exp/transformers-vision/

CIE Assessment Pattern (50 Marks – Lab)

RBT Levels		Test (s)	Weekly Assessment
		20	30
L1	Remember	-	-
L2	Understand	-	10
L3	Apply	10	10
L4	Analyze	10	10
L5	Evaluate	-	-
L6	Create	-	-

SEE Assessment Pattern (50 Marks – Lab)

RBT Levels		Exam Marks Distribution (50)
L1	Remember	05
L2	Understand	05
L3	Apply	20
L4	Analyze	20
L5	Evaluate	-
L6	Create	-

Suggested Learning Resources:
Reference Books:

1) Francois Chollet, “Deep Learning with Python”, 2nd Edition, Publisher: Manning Publications, 2021, ISBN: 9781617296864

2) Charu C. Aggarwal, “Neural Networks and Deep Learning: A Textbook”, Publisher: Springer, 2018, ISBN: 9783319944623

ADVANCED PROBLEM SOLVING METHODOLOGIES

Course Code	**24SDK66**	**CIE Marks**	**50**
L:T:P:S	**0:0:0:0**	**SEE Marks**	**-**
Hrs / Week	**2**	**Total Marks**	**50**
Credits	**0**	**Exam Hours**	**02**

Course outcomes:
Upon successful completion of this course, the student will be able to:

24SDK66.1	Infer the complex problems using the concepts of data structures and C programming
24SDK66.2	Apply object-oriented programming concepts in C++and Java to solve real time problem statements.
24SDK66.3	Solve real-world problem using python and C#
24SDK66.4	Develop the skills of handling data base queries and procedures

Mapping of Course Outcomes to Program Outcomes and Program Specific Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
24SDK66.1	3	3	-	-	2	-	-	-	-	-	-
24SDK66.2	2	3	3	-	3	-	-	-	-	-	-
24SDK66.3	2	2	3	2	3	-	-	-	-	-	-
24SDK66.4	2	3	3	-	3	-	-	-	-	-	-

MODULE-1	**Problem Solving On Data Structures and C**	**24SDK66.1**	**6 Hours**

Data Structures using C: Stack and queues, list, graph, tree, sorting and searching, Hash functions
Advanced C programming: Pointers, Recursion, Functions, Structure, Union, C Preprocessor

MODULE-2	**Problem Solving on Object Oriented Programming Using CPP**	**24SDK66.2**	**6 Hours**

Object Oriented Programming: Inheritance, Polymorphism, Exception handling, File Handling, Predefined function, Void function, Name spaces, Input and output streams.

MODULE-3	**Problem Solving on JAVA And XML**	**24SDK66.2**	**6 Hours**

Object oriented programming using Java: Inheritance, Polymorphism, Abstract class and Interface, Collections, Exception handling, Streams, Functional Interface.
XML: DTD, Schema, Server Path, DOM, XSLT, Name Space, AJAX.

MODULE-4	**Problem Solving Using C # And Python**	**24SDK66.3**	**6 Hours**

Python: Functions, iterators, Object oriented Programming, Exception Handling, Packages, Frame works- Django, Collections.
C#: Object oriented Programming, Delegate, Collections and generic, Name space.

MODULE-5	Scenario Based Problems On DBMS	24SDK66.4	6 Hours

ER Model, SQL- DDL, DML, TCL, DCL, Joins, subquery, PL/SQL-Index, Sequence, procedures and functions, normalization, B tree, B+ tree, Forms.

Note:

1. **Students shall solve the programming exercises and scenario-based problems available on the designated portal as part of the prescribed boot camp.**
2. **The CIE assessment and evaluation will be as per the guidelines framed by CDC.**

CIE Assessment Pattern (50 Marks – Theory)

RBT Levels		Marks Distribution
		Tests
		50
L1	Remember	5
L2	Understand	10
L3	Apply	20
L4	Analyze	15
L5	Evaluate	-
L6	Create	-

Suggested Learning Resources:

Reference Books:

1. Martin C Brown, "Python-The Complete Reference", Mc Graw Hill, 4th edition, 2020
2. Reema Tharega, "Data Structures using C", Oxford University Press, 2020
3. Ullakirch-Prinz, "A complete guide to program in C++", Jonas and Bartlett Learning, 2022
4. Kathy Sierra, "Headfirst Java", O'reilly Media, 2021
5. Andrew Stellman, "Headfirst C#", O'reilly Media, 2021

Web links and Video Lectures (e-Resources):

1. https://www.learncpp.com/
2. https://www.programiz.com/dsa
3. https://code.visualstudio.com/Docs/languages/csharp
4. https://www.udemy.com/course/the-complete-java-course-from-basics-to-advanced/?couponCode=ST16MT70224

Activity-Based Learning (Suggested Activities in Class)/ Practical Based learning

- Analysis of industry relevant use cases
- Problem solving on scenario-based questions
- Placement portal practice sessions

CAPSTONE PROJECT

Course Code	**24MEE67**	**CIE Marks**	**50**
L: T:P:S	**0:0:2:0**	**SEE Marks**	**50**
Hrs / Week	**2**	**Total Marks**	**100**
Credits	**02**	**Exam Hours**	**03**

Course outcomes:

At the end of the course, the student will be able to:

24MEE67.1	Identify an open ended problem in area of mechanical engineering.
24MEE67.2	Identify the methods and materials required for the project work
24MEE67.3	Apply the theoretical concepts to solve industrial problems with teamwork and multidisciplinary approach.
24MEE67.4	Formulate and implement innovative ideas for social and environmental benefit
24MEE67.5	Analyze the results to come out with concrete solutions
24MEE67.6	Demonstrate professionalism with ethics; present effective communication skills and relate engineering issues to broader societal context

CAPSTONE Project:: Guiding Principles for CAPSTONE Project

Project Overview:

- Clearly define the project's scope, objectives, and expected outcomes.
- Provide a brief description of the problem the project aims to solve or the functionality it should implement.

Project Milestones:

- Set clear project milestones and deadlines for various phases, such as planning, design, implementation, testing, and presentation.

Project Requirements:

- List the specific features or functionality that students need to implement in their projects.
- Clearly state any constraints or limitations they should be aware of during development.

Testing and Quality Assurance:

- Incorporate testing practices into their development process.
- Specify the types of testing (e.g., unit testing, integration testing)

Collaboration and Communication:

- If the project involves teamwork, outline expectations for collaboration, including communication channels and responsibilities within the team.

Documentation:

- Emphasize the importance of thorough documentation throughout the project.
- Require students to maintain documentation for code, design, and usage instructions.

Presentation:

- Require students to present their projects to the class, explaining their design choices, challenges faced, and how they overcame them.

Text Book	Text Book 1 & 2

CIE Assessment Pattern (50 Marks – Reviews as per the rubric statements defined)

RBT Levels		Exam Marks Distribution (50)
L1	Remember	-
L2	Understand	-
L3	Apply	20
L4	Analyze	10
L5	Evaluate	10
L6	Create	10

SEE Assessment Pattern (50 Marks – Theory)

RBT Levels		Exam Marks Distribution (50)
L1	Remember	-
L2	Understand	-
L3	Apply	20
L4	Analyze	10
L5	Evaluate	10
L6	Create	10

Suggested Learning Resources:

Text Books:

1. Kothari, C.R., Research Methodology: Methods and Techniques. New Age International.2018, ISBN-13: 978-8122436235

2) Garg, B.L., Karadia, R., Agarwal, F. and Agarwal, U.K. , An introduction to Research Methodology, RBSA Publishers. 2015, ISBN-13: 978-8176111652

3) Ranjithkumar, research methodology, saga publications,4th edition, 2014, ISBN-13- 978- 9351501336

Reference Books:

1.Anderson, T. W., An Introduction to Multivariate Statistical Analysis, Wiley Eastern Pvt., Ltd., New Delhi.2011, ISBN-13: 978-8126524488

2) Montgomary, Douglas C. &Runger, George C.Applied Statistics & probability for Engineers (Wiley India), 2016, ISBN-13: 978-1118539712

Web links and Video Lectures (e-Resources):

- **https://www.youtube.com/watch?v=YScxVF6ZcYI**
- **https://www.youtube.com/watch?v=9WMgaulAJ-0**

Activity-Based Learning (Suggested Activities in Class)/ Practical Based learning

These challenging mini project activities can provide students with opportunities to think critically, apply their knowledge, and develop problem-solving skills in a practical context.

Interdisciplinary Projects:

- Encourage collaboration among students from different disciplines to work on projects that require diverse expertise.

Prototype Development:

- Challenge students to create a prototype of a product or device.

Simulation and Modelling:

- Task students with creating computer simulations or mathematical models to solve complex problems or simulate real-world scenarios.

Humanitarian and Social Impact Projects:

- Challenge students to develop projects that address social or humanitarian issues, such as providing clean water solutions, designing low-cost healthcare devices, or improving education in underserved communities.

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Environmental Sustainability Projects:

- Challenge students to propose and implement sustainability initiatives or renewable energy projects.

Scientific Research Projects:

- Assign students to conduct scientific research experiments, gather data, and present findings.

NATIONAL SERVICE SCHEME

Course Code	**24NSS50, 24NSS60**	**CIE Marks (each Semester)**	**50**
L:T:P:S	**0:0:0:0**	**SEE Marks**	**--**
Hrs / Week	**2**	**Total Marks**	**50 x 4 = 200**
Credits	**00**	**Exam Hours**	**02**

Course outcomes:
At the end of the course, the student will be able to:

24NSSX0.1	Understand the importance of his / her responsibilities towards society.
24NSSX0.2	Analyse the environmental and societal problems/issues and will be able to design solutions for the same.
24NSSX0.3	Evaluate the existing system and to propose practical solutions for the same for sustainable development. Implement government or self-driven projects effectively in the field.
24NSSX0.4	Develop capacity to meet emergencies and natural disasters & practice national integration and social harmony in general.

Mapping of Course Outcomes to Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
24NSSX0.1	-	-	-	-	-	3	3	2	-	-	1
24NSSX0.2	-	-	-	-	-	3	3	2	-	-	1
24NSSX0.3	-	-	-	-	-	3	3	2	-	-	1
24NSSX0.4	-	-	-	-	-	3	3	2	-	-	1

Semester/ Course Code	CONTENT	COs	HOURS
3RD 24NSS30	1. Organic farming, Indian Agriculture (Past, Present and Future) Connectivity for marketing 2. Waste management–Public, Private and Govt organization, 5R's. 3. Setting of the information imparting club for women leading to contribution in social and economic issues.	24NSS30.1, 24NSS30.2, 24NSS30.3, 24NSS30.4	30 HRS
4TH 24NSS40	4. Water conservation techniques – Role of different stakeholders– Implementation. 5. Preparing an actionable business proposal for enhancing the village income and approach for implementation. 6. Helping local schools to achieve good results and enhance their enrolment in Higher/ technical/ vocational education.	24NSS40.1, 24NSS40.2, 24NSS40.3, 24NSS40.4	30 HRS
5TH	7. Developing Sustainable Water management system for rural areas and implementationapproaches. 8. Contribution to any national level initiative of Government	24NSS50.1, 24NSS50.2,	30 HRS

24NSS50	of India. Foreg. Digital India, Skill India, Swachh Bharat, Atmanirbhar Bharath, Make in India, Mudra scheme, Skill developmentprograms etc. **9.** Spreading public awareness under rural outreach programs. (minimum 5 programs).	24NSS50.3, 24NSS50.4	
6TH 24NSS60	**10.** Organize National integration and social harmony events / workshops / seminars. (Minimum TWO programs). **11.** Govt. school Rejuvenation and helping them to achieve good infrastructure.	24NSS60.1, 24NSS60.2, 24NSS60.3, 24NSS60.4	30 HRS

CIE Assessment Pattern (50 Marks – Activity based) –

CIE component for every semester	Marks
Presentation - 1 Selection of topic, PHASE - 1	10
Commencement of activity and its progress - PHASE - 2	10
Case study-based Assessment Individual performance	10
Sector wise study and its consolidation	10
Video based seminar for 10 minutes by each student at the end of semester with Report.	10
Total marks for the course in each semester	**50**

- Implementation strategies of the project (NSS work).
- The last report should be signed by NSS Officer, the HOD and principal.
- At last report should be evaluated by the NSS officer of the institute.
- Finally, the consolidated marks sheet should be sent to the university and also to be made available at LIC visit.

Suggested Learning Resources:

Reference Books:

1. NSS Course Manual, Published by NSS Cell, VTU Belagavi.
2. Government of Karnataka, NSS cell, activities reports and its manual.
3. Government of India, NSS cell, Activities reports and its manual.

Pre-requisites to take this Course:

1. Students should have a service-oriented mindset and social concern.
2. Students should have dedication to work at any remote place, anytime with available resources and proper time management for the other works.
3. Students should be ready to sacrifice some of the time and wishes to achieve service-oriented targets on time.

Pedagogy:

- In every semester from 3rd semester to 6th semester, each student should do activities according to the scheme and syllabus.
- At the end of every semester student performance has to be evaluated by the NSS officer for the assigned activity progress and its completion.
- At last, in 6th semester consolidated report of all activities from 3rd to 6th semester, compiled report should be submitted as per the instructions.
- State the need for NSS activities and its present relevance in the society and provide real-life examples.
- Support and guide the students for self-planned activities.
- NSS coordinator will also be responsible for assigning homework, grading assignments and quizzes, and documenting students' progress in real activities in the field.

- Encourage the students for group work to improve their creative and analytical skills.

Plan of Action:

- Student/s in individual or in a group Should select any one activity in the beginning of each semester till end of that respective semester for successful completion as per the instructions of NSS officer with the consent of HOD of the department.
- At the end of every semester, activity report should be submitted for evaluation.
- Practice Session Description:
    - Lecture session by NSS Officer
    - Students Presentation on Topics
    - Presentation - 1, Selection of topic, PHASE – 1
    - Commencement of activity and its progress - PHASE – 2
    - Execution of Activity
    - Case study-based Assessment, Individual performance
    - Sector/ Team wise study and its consolidation
    - Video based seminar for 10 minutes by each student at the end of semester with Report.

Sl No	Topic	Groupsize	Location	Activity execution	Reporting	Evaluation of the Topic
1.	Organic farming, IndianAgriculture (Past, Present and Future) Connectivity for marketing.	May be individual or team	Farmers land/Villages/ roadside / Community area / College campus	Site selection /proper consultation/ Continuous monitoring/ Information board	Report should be submitted byindividual to the concerned evaluation authority	Evaluation as per the rubrics of scheme and syllabus by NSS officer
2.	Waste management– Public, Private and Govtorganization, 5 R's.	May be individual or team	Villages/ City Areas / Grama panchayat/ public associations/ Government Schemes officers/ campus	Site selection /proper consultation/ Continuous monitoring/ Information board	Report should be submitted byindividual to the concerned evaluation authority	Evaluation as per the rubrics of scheme and syllabus by NSS officer
3.	Setting of the information imparting club for women leading to contributionin social and economic issues.	May be individual or team	Women empowerment groups/ Consulting NGOs & Govt Teams / College campus	Group selection/pro per consultation/ Continuous monitoring/ Information board	Report should be submitted byindividual to the concerned evaluation authority	Evaluation as per the rubrics of scheme and syllabus by NSS officer

4.	Water conservation techniques – Role of different stakeholders– Implementation.	May be individual or team	Villages/ City Areas / Grama panchayat/ public associations/ Government Schemes officers/ campus	site selection / proper consultation/ Continuous monitoring/ Information board	Report should be submitted byindividual to the concerned evaluation authority	Evaluation as per the rubrics of scheme and syllabus by NSS officer
5.	Preparing an actionable business proposal for enhancing the village income and approach for implementation.	May be individual or team	Villages/ City Areas / Grama panchayat/ public associations/ Government Schemes officers/ campus	Group selection/proper consultation/ Continuous monitoring/ Information board	Report should be submitted byindividual to the concerned evaluation authority	Evaluation as per the rubrics of scheme and syllabus by NSS officer
6.	Helping local schools toachieve good results and enhance their enrolment in Higher/ technical/ vocational education.	May be individual or team	Local government / private/ aided schools/Government Schemes officers	School selection/proper consultation/ Continuous monitoring/ Information board	Report should be submitted byindividual to the concerned evaluation authority	Evaluation as per the rubrics of scheme and syllabus by NSS officer
7.	Developing SustainableWater management system for rural areas and implementation approaches.	May be individual or team	Villages/ City Areas / Grama panchayat/ public associations/ Government Schemes officers/ campus	site selection/proper consultation/ Continuous monitoring/ Information board	Report should be submitted byindividual to the concerned evaluation authority	Evaluation as per the rubrics of scheme and syllabus by NSS officer
8.	Contribution to any national level initiative of Government of India.For eg. Digital India, Skill India, Swachh Bharat, Atmanirbhar Bharath, Make in India, Mudra scheme,Skill	May be individual or team	Villages/ City Areas / Grama panchayat/ public associations/ Government Schemes officers/ campus	Group selection/proper consultation/ Continuous monitoring / Information board	Report should be submitted byindividual to the concerned evaluation authority	Evaluation as per the rubrics of scheme and syllabus by NSS officer

	development programs etc.					
9.	Spreading public awareness under ruraloutreach programs. (minimum5 programs)	May be individual or team	Villages/ City Areas / Grama panchayat/ public associations/ Government Schemes officers/ campus	Group selection/pro per consultation/ Continuous monitoring / Information board	Report should be submitted byindividual to the concerned evaluation authority	Evaluation as per the rubrics of scheme and syllabus by NSS officer
10.	Organize National integration and socialharmony events / workshops / seminars. (Minimum 02 programs).	May be individual or team	Villages/ City Areas / Grama panchayat/ public associations/ Government Schemes officers/ campus	Place selection/pro per consultation/ Continuous monitoring / Information board	Report should be submitted byindividual to the concerned evaluation authority	Evaluation as per the rubrics of scheme and syllabus by NSS officer
11.	Govt. school Rejuvenation and helping them to achieve good infrastructure.	May be individual or team	Villages/ City Areas / Grama panchayat/ public associations/ Government Schemes officers/ campus	Place selection/pro per consultation/ Continuous monitoring / Information board	Report should be submitted byindividual to the concerned evaluation authority	Evaluation as per the rubrics of scheme and syllabus by NSS officer

PHYSICAL EDUCATION AND SPORTS

Course Code	**24PED50, 24PED60**	**CIE Marks (each semester)**	**50**
L:T:P:S	**0:0:0:0**	**SEE Marks**	**--**
Hrs / Week	**2**	**Total Marks**	**50 x 4= 200**
Credits	**00**	**Exam Hours**	**02**

Course outcomes:

At the end of the course, the student will be able to:

24PEDX0.1	Understand the fundamental concepts and skills of Physical Education, Health, Nutrition and Fitness
24PEDX0.2	Create consciousness among the students on Health, Fitness and Wellness in developing and maintaining a healthy lifestyle
24PEDX0.3	Perform in the selected sports or athletics of student's choice and participate in the competition at regional/state / national / international levels.
24PEDX0.4	Understand the roles and responsibilities of organization and administration of sports and games

Mapping of Course Outcomes to Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
24PEDX0.1	-	-	-	-	-	2	-	3	3	-	-	2
24PEDX0.2	-	-	-	-	-	2	-	3	3	-	-	2
24PEDX0.3	-	-	-	-	-	2	-	3	3	-	-	2
24PEDX0.4	-	-	-	-	-	2	-	3	3	-	-	2

Semester	CONTENT	COs	HOURS
3RD 24PED30	**Module 1: Orientation** A. Lifestyle, B. Fitness C. Food & Nutrition D. Health & Wellness E. Pre-Fitness test.	24PED30.1, 24PED30.2	5 HRS
	Module 2: General Fitness & Components of Fitness A. Warming up (Free Hand exercises) B. Strength – Push-up / Pull-ups C. Speed – 30 Mtr Dash D. Agility – Shuttle Run E. Flexibility – Sit and Reach F. Cardiovascular Endurance – Harvard step Test	24PED30.2, 24PED30.3	15 HRS
	Module 3: Recreational Activities A. Postural deformities. B. Stress management. C. Aerobics. D. Traditional Games.	24PED30.3, 24PED30.4	10 HRS

4TH 24PED40	**Module 1: Ethics and Moral Values** A. Ethics in Sports B. Moral Values in Sports and Games	24PED40.1, 24PED40.2	5 HRS
	Module 2: Specific Games (Anyone to be selected by the student) A. Volleyball – Attack, Block, Service, Upper Hand Pass and Lower hand Pass. B. Throwball – Service, Receive, Spin attack, Net Drop & Jump throw. C. Kabaddi – Hand touch, Toe Touch, Thigh Hold, Ankle hold and Bonus. D. Kho-Kho – Giving Kho, Single Chain, Pole dive, Pole turning, 3-6 Up. E. Table Tennis – Service (Fore Hand & Back Hand), Receive (Fore Hand & Back Hand), Smash. F. Athletics (Track / Field Events) – Any event as per availability of Ground.	24PED40.3	20 HRS
	Module 3: Role of Organization and administration	24PED40.4	5 HRS
5TH 24PED50	**Fitness Components:** Meaning and Importance, Fit India Movement, Definition of fitness, Components of fitness, Benefits of fitness, Types of fitness and Fitness tips. **Practical Components:** Speed, Strength, Endurance, Flexibility, and Agility **Athletics**: 1. Track -Sprints: • Starting Techniques: Standing start and Crouch start (its variations) use of Starting Block. • Acceleration with proper running techniques. • Finishing technique: Run Through, Forward Lunging and Shoulder Shrug. 2. Jumps- Long Jump: Approach Run, Take-off, Flight in the air (Hang Style/Hitch Kick)and Landing 3. Throws- Shot Put: Holding the Shot, Placement, Initial Stance, Glide, Delivery Stance and Recovery (Perry O'Brien Technique) **Handball OR Ball Badminton** **Handball:** A. Fundamental Skills 1. Catching, Throwing and Ball control, 2. Goal Throws: Jumpshot, Centershot, Diveshot, Reverseshot. 3. Dribbling: High and low. 4. Attack and counter attack, simple counter attack, counter attack from two wings and center. 5. Blocking, Goal Keeping and Defensive skills. 6. Game practice with application of Rules and Regulations. B. Rules and their interpretations and duties of officials **Ball badminton:** A. Fundamental Skills	24PED50.1, 24PED50.2, 24PED50.3, 24PED50.4	Total 30 Hrs/ Semester 2 Hrs/week

	1. Basic Knowledge: Various parts of the Racket and Grip. 2. Service: Short service, Long service, Long-high service. 3. Shots: Overhead shot, Defensive clearshot, Attacking clearshot, Dropshot, Netshot, Smash. 4. Game practice with application of Rules and Regulations. B. Rules and their interpretation and duties of officials.		
6TH 24PED60	**Athletics**: 1. Track -110 Mtrs and 400Mtrs: • Hurdling Technique: Lead leg Technique, Trail leg Technique, Side Hurdling, Over the Hurdles • Crouch start (its variations) use of Starting Block. • Approach to First Hurdles, In Between Hurdles, Last Hurdles to Finishing. 2. Jumps- High jump: Approach Run, Take-off, Bar Clearance (Straddle) and Landing. 3. Throws- Discus Throw: Holding the Discus, Initial Stance Primary Swing, Turn, Release and Recovery (Rotation in the circle). **Football OR Hockey** **Football:** A. Fundamental Skills 1. Kicking: Kicking the ball with inside of the foot, Kicking the ball with Full Instep of the foot, Kicking the ball with Inner Instep of the foot, Kicking the ball with Outer Instep of the foot and Lofted Kick. 2. Trapping: Trapping- the Rolling ball, and the Bouncing ball with sole of the foot. 3. Dribbling: Dribbling the ball with Instep of the foot, Dribbling the ball with Inner and Outer Instep of the foot. 4. Heading: In standing, running and jumping condition. 5. Throw-in: Standing throw-in and Running throw-in. 6. Feinting: With the lower limb and upper part of the body. 7. Tackling: Simple Tackling, Slide Tackling. 8. Goal Keeping: Collection of Ball, Ball clearance-kicking, throwing and deflecting. 9. Game practice with application of Rules and Regulations. A. Rules and their interpretation and duties of officials. **Hockey:** A. Fundamental Skills 1. Passing: Short pass, Longpass, pushpass, hit 2. Trapping. 3. Dribbling and Dozing 4. Penalty stroke practice. 5. Penalty corner practice. 6. Tackling: Simple Tackling, Slide Tackling. 7. Goal Keeping, Ball clearance- kicking, and deflecting. 8. Game practice with application of Rules and Regulations.	24PED60.1, 24PED60.2, 24PED60.3, 24PED60.4	Total 30 Hrs/ Semester 2 Hrs/week

	B. Rules and their interpretation and duties of officials		

CIE Assessment Pattern (50 Marks – Practical) –

CIE to be evaluated every semester end based on practical demonstration of Sports and Athletics activities learnt in the semester.

CIE	Marks
Participation of student in all the modules	10
Quizzes – 2, each of 7.5 marks	15
Final presentation / exhibition / Participation in competitions/ practical on specific tasks assigned to the students	25
Total	**50**

Suggested Learning Resources:

Reference Books:

1. Saha, A.K. Sarir Siksher Ritiniti, Rana Publishing House, Kalyani.
2. Bandopadhyay, K. Sarir Siksha Parichay, Classic Publishers, Kolkata.
3. Petipus, et.al., Athlete's Guide to Career Planning, Human Kinetics.
4. Dharma, P.N. Fundamentals of Track and Field, Khel Sahitya Kendra, New Delhi.
5. Jain, R. Play and Learn Cricket, Khel Sahitya Kendra, New Delhi.
6. Vivek Thani, Coaching Cricket, Khel Sahitya Kendra, New Delhi.
7. Saha, A.K. Sarir Siksher Ritiniti, Rana Publishing House, Kalyani.
8. Bandopadhyay, K. Sarir Siksha Parichay, Classic Publishers, Kolkata
9. Naveen Jain, Play and Learn Basketball, Khel Sahitya Kendra, New Delhi.
10. Dubey H.C., Basketball, Discovery Publishing House, New Delhi.
11. Rachana Jain, Teach Yourself Basketball, Sports Publication.
12. Jack Nagle, Power Pattern Offences for Winning basketball, Parker Publishing Co., New York.
13. Renu Jain, Play and Learn Basketball, Khel Sahitya Kendra, New Delhi.
14. SallyKus, Coaching Volleyball Successfully, Human Kinetics.

YOGA

Course Code	**24YOG50, 24YOG60**	**CIE Marks**	**50**
L:T:P:S	**0:0:0:0**	**SEE Marks**	**--**
Hrs / Week	**2**	**Total Marks**	**50 x 4 = 200**
Credits	**00**	**Exam Hours**	**02**

Course outcomes:
At the end of the course, the student will be able to:

24YOGX0.1	Understanding the origin, history, aim and objectives of Yoga
24YOGX0.2	Become familiar with an authentic foundation of Yogic practices
24YOGX0.3	Practice different Yogic methods such as Suryanamaskara, Pranayama and some of the Shat
24YOGX0.4	Use the teachings of Patanjali in daily life.

Mapping of Course Outcomes to Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
24YOGX0.1	-	-	-	-	-	3	-	-	-	-	1
24YOGX0.2	-	-	-	-	-	3	-	-	-	-	1
24YOGX0.3	-	-	-	-	-	3	-	-	-	-	1
24YOGX0.4	-	-	-	-	-	3	-	-	-	-	1

Semester / Course Code	CONTENT	COs	HOURS
3rd 24YOG30	**Introduction of Yoga:** Aim and Objectives of yoga, Prayer: Yoga, its origin, history and development. Yoga, its meaning, definitions. Different schools of yoga, importance of prayer **Brief introduction of yogic practices for common man:** Yogic practices for common man to promote positive health **Rules and regulations:** Rules to be followed during yogic practices by practitioner **Misconceptions of yoga:** Yoga its misconceptions, Difference between yogic and non-yogic practices. **Suryanamaskara:** 1. Suryanamaskar prayer and its meaning, Need, importance and b of Suryanamaskar. 2. Suryanamaskar 12 count,2rounds **Different types of Asanas**: 1. Sitting: Padmasana, Vajrasana, Sukhasana 2. Standing: Vrikshana, Trikonasana, Ardhakati Chakrasana 3. Prone line: Bhujangasana, Shalabhasana 4. Supineline: Utthitadvipadasana, Ardhahalasana, Halasana	24YOG30.1, 24YOG30.2, 24YOG30.3, 24YOG30.4	Total 32 Hrs/ Semester 2 Hrs/week

4TH 24YOG40	**Suryanamaskara:** Suryanamaskar 12 count,4rounds **Brief introduction and importance of:** **Kapalabhati:** Revision of Kapalabhati -40strokes/min3rounds **Different types of Asanas**: 1. Sitting: Paschimottanasana, Ardha Ushtrasana, Vakrasana, Aakarna Dhanurasana 2. Standing: Parshva Chakrasana, Urdhva Hastothanasana, Hastapadasana 3. Prone line: Dhanurasana 4. Supine line: Karna Peedasana, Sarvangasana, Chakraasana **Patanjali's Ashtanga Yoga**: Asana, Pranayama **Pranayama:** Chandra Bhedana, Nadishodhana, Surya Bhedana	24YOG40.1, 24YOG40.2, 24YOG40.3, 24YOG40.4	Total 32 Hrs/ Semester 2 Hrs/week
5TH 24YOG50	**Kapalabhati:** Revision of Kapalabhati - 60strokes/min3rounds **Brief introduction and importance of:** **Different types of Asanas**: 1. Sitting: Yogamudra in Padmasana, Vibhakta Paschimottanasana, Yogamudra in Vajrasana 2. Standing: Parivritta Trikonasana, Utkatasana, Parshvakonasana 3. Prone line: Padangushtha Dhanurasana, Poorna Bhujangasana / Rajakapotasana 4. Supine line: Navasana/Noukasana, Pavanamuktasana, Sarvanga **Patanjali's Ashtanga Yoga**: Pratyahara, Dharana **Pranayama:** Ujjayi, Sheetali, Sheektari	24YOG50.1, 24YOG50.2, 24YOG50.3, 24YOG50.4	Total 32 Hrs/ Semester 2 Hrs/week
6TH 24YOG60	**Kapalabhati:** Revision of Kapalabhati – 80 strokes/min3rounds **Brief introduction and importance of:** **Different types of Asanas**: 1. Sitting: Bakasana, Hanumanasana, Ekapada Rajakapotasana 2. Standing: Parivritta Trikonasana, Utkatasana, Parshvakonasana 3. Supine line: Setubandhasana, Shavasanaa (Relaxation posture) 4. Balancing: Sheershasana **Patanjali's AshtangaYoga**: Dhyana (Meditation), Samadhi **Pranayama:** Bhastrika, Bhramari, Ujjai **Shat Kriyas:** Jalaneti and sutraneti, Sheetkarma Kapalabhati	24YOG60.1, 24YOG60.2, 24YOG60.3, 24YOG60.4	Total 32 Hrs/ Semester 2 Hrs/week

CIE Assessment Pattern (50 Marks – Practical)

CIE to be evaluated every semester based on practical demonstration of Yogasana learnt in the semester and internal tests (objective type)

CIE	Marks
Avg of Test 1 and Test 2	25
Demonstration of Yogasana	25
Total	**50**

Suggested Learning Resources:

Reference Books:

4. Swami Kuvulyananda: Asma (Kavalyadhama, Lonavala)
5. Tiwari, O P: Asana Why and How
6. Ajitkumar: Yoga Pravesha (Kannada)
7. Swami Satyananda Saraswati: Asana Pranayama, Mudra, Bandha (Bihar School of yoga, Munger)
8. Swami Satyananda Saraswati: Surya Namaskar (Bihar School of yoga, Munger)

9. Nagendra H R: The art and science of Pranayama
10. Tiruka: Shatkriyegalu (Kannada)
11. Iyengar B K S: Yoga Pradipika (Kannada)
12. Iyengar B K S: Light on Yoga (English)

Web links and Video Lectures (e-Resources):

- **https://youtu.be/KB-TYlgd1wE**
- **https://youtu.be/aa-TG0Wg1Ls**

Appendix A: List of Assessment Patterns

S.NO	Pattern of Assessments
1	Assignments
2	Group Discussions
3	Case Study / Caselets
4	Practical-Orientation on Design Thinking
5	Participatory & Industry-Integrated Learning
6	Practical Activities / Problem Solving Exercises
7	Class Presentations
8	Analysis of Industry / Technical / Business Reports
9	Reports on Industrial Visit
10	Industrial / Social / Rural Projects
11	Participation in external seminars / Workshops
12	Any Other Academic Activity
13	Online / Offline Quizzes

APPENDIX B: Outcome Based Education

Outcome-based education (OBE) is an educational theory that bases each part of an educational system around goals (outcomes). By the end of the educational experience each student should have achieved the goal. There is no specified style of teaching or assessment in OBE; instead classes, opportunities, and assessments should all help students achieve the specified outcomes.

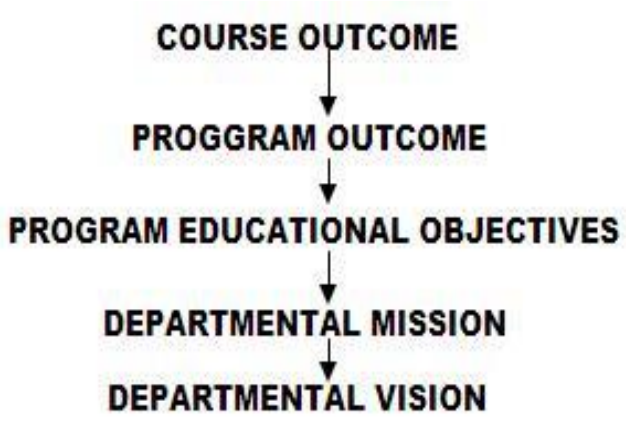
There are three educational Outcomes as defined by the National Board of Accreditation:

Program Educational Objectives: The Educational objectives of an engineering degree program are the statements that describe the expected achievements of graduate in their career and also in particular what the graduates are expected to perform and achieve during the first few years after graduation. [nbaindia.org]

Program Outcomes: What the student would demonstrate upon graduation. Graduate attributes are separately listed in Appendix C

Course Outcome: The specific outcome/s of each course/subject that is a part of the program curriculum. Each subject/course is expected to have a set of Course Outcomes

Mapping of Outcomes



APPENDIX C: The Graduate Attributes of NBA

Engineering knowledge: Apply knowledge of mathematics, natural science, computing, engineering fundamentals and an engineering specialization as specified in WK1 to WK4 respectively to develop to the solution of complex engineering problems.

Problem analysis: Identify, formulate, review research literature and analyze complex engineering problems reaching substantiated conclusions with consideration for sustainable development. (WK1 to WK4)

Design/development of solutions: Design creative solutions for complex engineering problems and design/develop systems/components/processes to meet identified needs with consideration for the public health and safety, whole-life cost, net zero carbon, culture, society and environment as required. (WK5).

Conduct investigations of complex problems: Conduct investigations of complex engineering problems using research-based knowledge including design of experiments, modelling, analysis & interpretation of data to provide valid conclusions. (WK8)..

Engineering Tool Usage: Create, select and apply appropriate techniques, resources and modern engineering & IT tools, including prediction and modelling recognizing their limitations to solve complex engineering problems. (WK2 and WK6).

The Engineer and The World: Analyze and evaluate societal and environmental aspects while solving complex engineering problems for its impact on sustainability with reference to economy, health, safety, legal framework, culture and environment. (WK1, WK5, and WK7) .

Ethics: Apply ethical principles and commit to professional ethics, human values, diversity and inclusion; adhere to national & international laws. (WK9).

Individual and Collaborative Team work: Function effectively as an individual, and as a member or leader in diverse/multi-disciplinary teams.

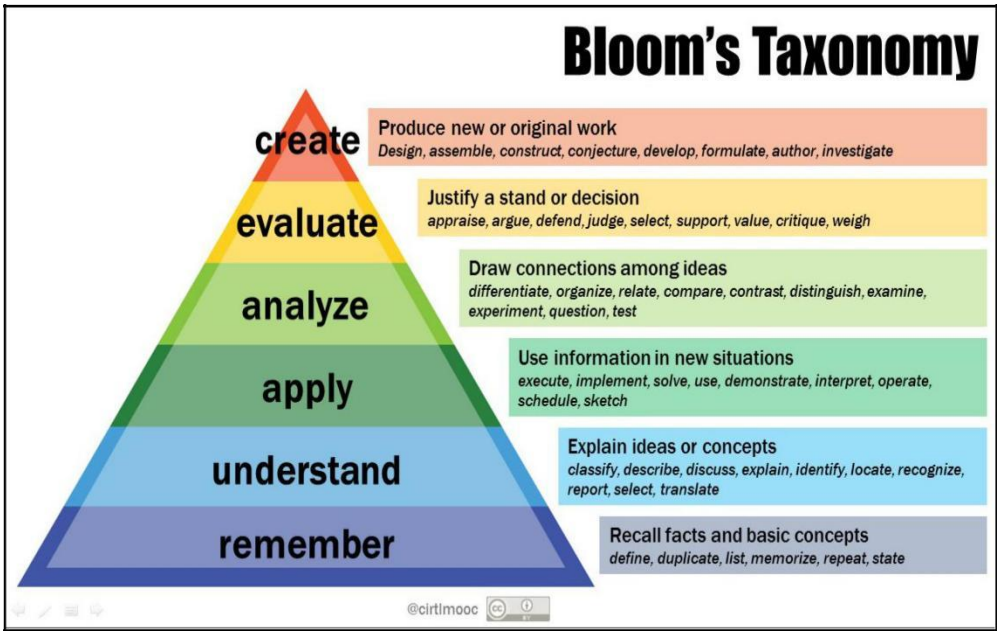
Communication: Communicate effectively and inclusively within the engineering community and society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations considering cultural, language, and learning differences.

Project management and finance: Apply knowledge and understanding of engineering management principles and economic decision-making and apply these to one's own work, as a member and leader in a team, and to manage projects and in multidisciplinary environments..

Life-long learning: Recognize the need for, and have the preparation and ability for i) independent and life-long learning ii) adaptability to new and emerging technologies and iii) critical thinking in the broadest context of technological change. (WK8).

APPENDIX D: BLOOM'S TAXONOMY

Bloom's taxonomy is a classification system used to define and distinguish different levels of human cognition—i.e., thinking, learning, and understanding. Educators have typically used Bloom's taxonomy to inform or guide the development of assessments (tests and other evaluations of student learning), curriculum (units, lessons, projects, and other learning activities), and instructional methods such as questioning strategies.



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