Agnel Charities

Fr. C. Rodrigues Institute of Technology

Sector 9A, Vashi, Navi Mumbai, 400703, Maharashtra, India

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An Autonomous Institute Affiliated to the University of Mumbai

Department of Mechanical Engineering

Curriculum Structure

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Third Year Syllabus

Prepared by : Board of Studies for Mechanical Engineering

Approved By: Academic Council of Fr. C. Rodrigues Institute of Technology Effective from :2025-26

Revision: 2024.1

PREAMBLE - DEAN ACADEMICS

Accelerating Towards Excellence: Unveiling a New Era in Education

Dear Students, Faculty, and Stakeholders,

It is with great pleasure and anticipation that we introduce the newly designed curriculum for autonomy at Agnel Charities' Fr. C. Rodrigues Institute of Technology. This pioneering initiative aims to revolutionize engineering education, ensuring our graduates are equipped with not only technical prowess but also the holistic skills necessary for thriving in today's dynamic professional landscape.

1. **Purpose of Autonomy:** Our commitment to autonomy is rooted in the imperative to bridge the gap between academia and industry. We envision education as a catalyst for individual growth, fostering self-sustainability and enhancing employability. Through our curriculum, we strive to nurture engineers who not only excel in their fields but also contribute meaningfully to society.
2. **Curriculum Design: A Top-to-Down Approach:** Our curriculum is meticulously crafted with a top-to-down approach, encompassing all 12 attributes of Program Outcomes mandated by regulatory bodies. Emphasizing a blend of theoretical knowledge and practical application, it is designed to cultivate well-rounded professionals capable of tackling real-world challenges with confidence and competence.
3. **Alignment with National Education Policy-2020:** In adherence to the guidelines laid out in the National Education Policy-2020, our curriculum embodies a multidisciplinary approach, offering a diverse array of core and elective courses. It integrates hands-on learning experiences such as mini and major projects, skill-based labs, and one-semester internships to nurture innovation and problem-solving skills. Additionally, the inclusion of value-added courses, honours, and minors ensures a comprehensive educational journey tailored to individual interests and aspirations.
4. **Opportunities for Teachers in Innovation:** We recognize the pivotal role of our faculty in shaping the educational experience. Our curriculum provides ample opportunities for teachers to innovate in teaching-learning methodologies and evaluation techniques. Through continuous professional development programs and collaborative platforms, we empower our educators to experiment with innovative pedagogies, leverage technology for enhanced learning outcomes, and implement novel assessment strategies. By fostering a culture of innovation among our faculty, we aim to enrich the learning experience and inspire a passion for lifelong learning among our students.

As we embark on this transformative journey, we invite all stakeholders to join us in shaping the future of engineering education. Together, let us strive towards excellence, innovation, and societal impact.

Sincerely,

Dean of Academics Agnel Charities' Fr. C. Rodrigues Institute of Technology

PREAMBLE - BOS CHAIRMAN

Dear Students and Stakeholders,

It is with great pleasure and anticipation that Board of Studies of Mechanical Engineering introduce the newly designed curriculum at Agnel Charities' Fr. C. Rodrigues Institute of Technology. We are committed to fostering a culture of innovation, excellence, and service in the field of mechanical engineering. As an autonomous institution, we embrace the responsibility of shaping the future of our profession and empowering our students to become proficient engineers, leaders, and global citizens.

Department has taken a lead in incorporating philosophy of outcome-based education in the process of curriculum development. Curriculum is aligned with Institute, Department vision and mission and with National Education Policy-2020. Program outcomes are based as per the guidelines mentioned in the NBA SAR-January 2016. Our department stands as a beacon of knowledge, dedicated to advancing the frontiers of mechanical engineering through cutting-edge research, interdisciplinary collaboration, and industry partnerships. We believe in the transformative power of education to inspire creativity, critical thinking, and ethical decision-making among our students.

Positioning of learning in real world is ensured to keep abreast of latest trends and technologies as per industry requirement. Well thought has been given to selection of courses while structuring the curriculum. Core courses, elective courses, Lab courses, skill-based lab courses and Honors/Minor verticals such as Electric Vehicle Technology, Supply Chain, 3D Printing, Data Science, Aeronautical Engineering are identified. Mechanical Engineering course integrates a range of experiential learning opportunities, including internships, mini and major projects, industry projects and collaborative research initiatives. Additionally, emphasis is placed on promoting a culture of lifelong learning, encouraging students to stay abreast of emerging trends, engage in continuous professional development, and contribute meaningfully to the advancement of the field.

Department has taken an initiative to design course syllabus by adapting leaner centered approach through backward design method facilitating the creation of more cohesive, clear and intentional learning experiences for learners. While designing the syllabus teacher has identified the desired results through setting the course and learning objectives aligned with Bloom's taxonomy and Performance Indicators. Teacher has identified the assessments that students will complete in order to demonstrate evidence of learning and even progress towards achievement of learning objectives. Based on this teacher has planned the contents. While planning the content points are considered as what enabling knowledge & skills will learner need in order to achieve desired results, what ways they will be evaluated along the way, what activities will equip learner with needed knowledge and skills, what will need to be taught and how should it best be done using pedagogical and innovative methods. The draft scheme and syllabus were presented to all stakeholders for receiving critical feedback and suggestions. Important and relevant suggestions were incorporated.

We invite all stakeholders to join us on this transformative educational journey, where students are empowered to become catalysts of innovation, drivers of change, and leaders of tomorrow's digital landscape. By embracing a holistic approach to learning, grounded in academic rigor, practical relevance, and ethical values, we strive to nurture a new generation of Mechanical Engineers poised to make a positive impact on society and shape a brighter future for generations to come.

Sincerely,
Chairman, Board of Studies – Mechanical Engineering,
Agnel Charities' Fr. C. Rodrigues Institute of Technology

Contents

A. Abbreviations

AEC	Ability Enhancement Course
AU	Audit Course
BSC	Basic Science Course including Mathematics
BSL	Basic Science Laboratory Course
ELC	Experiential Learning Course
ESC	Engineering Sciences Course
ESL	Engineering Sciences Laboratory Course
HMC	Honours or Minor Core Course
HML	Honours or Minor Laboratory
HMP	Honours or Minor Mini Project
HSS	Humanities Social Sciences and Management Course
IKS	Indian Knowledge System Course
INT	Internship
L	Lecture
LBC	Laboratory Course
LLC	Liberal Learning Course
MDM	Multidisciplinary Minor Course
MDL	Multidisciplinary Laboratory Course
MJP	Major Project
MNP	Mini Project
OEC	Open Elective Course
P	Practical
PCC	Program Core Course
PEC	Program Elective Course
RPC	Research Project Coursework
RPR	Research Project
SBL	Skill Based Laboratory
SEC	Skill Enhancement Course
T	Tutorial
VEC	Value Education Course

B. Credit Structure

1. B. Tech in Mechanical Engineering											
Type of Course	**Semester-wise Credit Distribution**									**FCRIT Credit Distribution**	**DTE Credit Distribution**
	I	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**Total**		
Basic Science Course (BSC)	08	08	--	--	--	--	--	--	**16**	**18**	**14-18**
Basic Science Laboratory Course (BSL)	01	01	--	--	--	--	--	--	**02**		
Engineering Science Course (ESC)	05	02	--	--	--	--	--	--	**07**	**16**	**12-16**
Engineering Science Laboratory Course (ESL)	04	05	--	--	--	--	--	--	**09**		
Program Core Course (PCC)	--	--	14	13	06	03	03	--	**39**	**50**	**44-56**
Laboratory Course (LBC)	--	--	02	03	03	01	02	--	**11**		
Program Elective (PEC)	--	--	--	--	03	03	06	03	**15**	**15**	**20**
Multidisciplinary Minor (MDM)	--	--	03	03	03	04	—	--	**13**	**13**	**14**
Multidisciplinary Laboratory Course (MDL)	--	--	--	--	--	01	--	--	**01**	**01**	
Open Elective (OEC)	--	--	--	--	--	--	03	03	**06**	**06**	**08**
Skill Enhancement Course (SEC)	01	01	--	--	--	--	--	--	**02**	**08**	**08**
Skill Based Laboratory (SBL)	--	--	02	02	--	02	--	--	**06**		
Ability Enhancement Course (AEC)	--	03	--	--	02	--	--	--	**05**	**05**	**04**
Humanities Social Sciences and Management (HSS)	--	--	02	--	02	--	02	--	**06**	**06**	**04**
Indian Knowledge System (IKS)	--	02	--	--	--	--	--	--	**02**	**02**	**02**
Value Education Course (VEC)	02	--	--	02	--	--	--	--	**04**	**04**	**04**
Experiential Learning Course (ELC)	--	--	--	--	--	02	--	--	**02**	**02**	**04**
Mini Project (MNP)	--	--	01	01	01	01	--	--	**04**	**10**	**04**
Major Project (MJP)	--	--	--	--	--	--	02	04	**06**		
Internship (INT)	--	--	--	--	--	--	--	08	**08**	**08**	**12**
Liberal Learning Course (LLC)	--	--	--	--	--	02	--	---	**02**	**02**	**04**
Total Credits	**21**	**22**	**24**	**24**	**20**	**19**	**18**	**18**	**166**	**166**	**160-176**

C Curriculum Structure and Examination Scheme for B. Tech in Mechanical Engineering

Curriculum Structure – TY Semester-V

Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		L	P	T	L	P	T	Total
MEPCC509	Mechanical Vibrations	3	--	--	3	--	--	3
MEPCC510	Fluid Mechanics and Machinery	3	--	--	3	--	--	3
XXMDM503	--	3	--	--	3	--	--	3
MEPEC501Y	Program Elective-I	3	--	--	3	--	--	3
MELBC506	Mechanical Vibrations Laboratory	--	2	--	--	1	--	1
MELBC507	Fluid Mechanics and Machinery	--	2	--	--	1	--	1
MELBC508	Computational Laboratory	--	2	--	--	1	--	1
AEC502	Professional Communication and Ethics-II	1	2	--	1	1	--	2
MEMNP503	Mini Project-2A	--	3	--	--	1	--	1
HSS502	Entrepreneurship	2	--	--	2	--	--	2
	Total	**15**	**11**	**--**	**15**	**5**	**--**	**20**

NOTE: Students who choose not to pursue Honours or Minor are welcome to register for the initial two courses of the fifth and sixth semesters' Honours or Minor track in 'Audit' mode (AU). This allows them to explore the course material without the expectation of earning a letter grade. Upon fulfilling the requirements in 'Audit' mode, their participation will be acknowledged on the grade sheet. Audit courses are excluded from grade point averages and have no impact on SGPI/CGPI calculations. For more information on Honours and Minor track courses, please refer to the Institute Handbook for Honours/Minor/Honours in Research degree programs.

Program Elective Course-I:

Students should take one PE from the following list of Program Elective Course- I.

Course Code	Program Elective-I
MEPEC5011	Finite Element Analysis
MEPEC5012	Computer Aided Engineering
MEPEC5013	Computational Fluid Dynamics

Examination Scheme – TY Semester-V

Course Code	Course Name	Examination Scheme					Total
		In-Semester Assessment$		End Sem Exam (ESE)	Exam Duration for Theory (in Hrs)		
		Continuous Assessment	Mid-Sem Exam		Mid - Sem	End-Sem	
MEPCC509	Mechanical Vibrations	20	30	50	1.5	2	100
MEPCC510	Fluid Mechanics and Machinery	20	30	50	1.5	2	100
XXMDM503	--	20	30	50	1.5	2	100
MEPEC501Y	Program Elective-I	20	30	50	1.5	2	100
MELBC506	Mechanical Vibrations Laboratory	25	--	25	--	--	50
MELBC507	Fluid Mechanics and Machinery Laboratory	25	--	25	--	--	50
MELBC508	Computational Laboratory	25	--	25	--	--	50
AEC502	Professional Communication and Ethics-II	50	--	--	--	--	50
MEMNP503	Mini Project-2A	50	--	--	--	--	50
HSS502	Entrepreneurship	50	--	--	--	--	50
	Total	**305**	**120**	**275**	--	--	**700**

$Please refer to the Curriculum Book of respective departments for guidelines on in-semester assessments for both theory and laboratory courses.

Curriculum Structure – TY Semester-VI

Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		L	P	T	L	P	T	Total
MEPCC611	Machine Design	3		--	3	--	--	3
XXMDM604	--	4		--	4	--	--	4
MEPEC602Y	Program Elective-II	3	--	--	3	--	--	3
MELBC609	Machine Design Laboratory	--	2	--	--	1	--	1
XXMDL601	--	--	2	--	--	1	--	1
MESBL603	CNC & 3D Printing Laboratory	--	4	--	--	2	--	2
MEMNP604	Mini Project-2B	--	3	--	--	1	--	1
ELC601	Research Methodology	2	--	--	2	--	--	2
LLC601Y*	Liberal Learning Course	2	--	--	2	--	--	2
	Total	**14**	**11**	**--**	**14**	**5**	**--**	**19**

NOTE: Students who choose not to pursue Honours or Minor are welcome to register for the initial two courses of the fifth and sixth semesters' Honours or Minor track in 'Audit' mode (AU). This allows them to explore the course material without the expectation of earning a letter grade. Upon fulfilling the requirements in 'Audit' mode, their participation will be acknowledged on the grade sheet. Audit courses are excluded from grade point averages and have no impact on SGPI/CGPI calculations. For more information on Honours and Minor track courses, please refer to the Institute Handbook for Honours/Minor/Honours in Research degree prorams.

Program Elective Course-II:
Students should take one PE from the following list of Program Elective Course- II.

Course Code	Program Elective-II
MEPEC6021	Refrigeration and Air Conditioning
MEPEC6022	Heating, Ventilation and Air Conditioning
MEPEC6023	Cryogenic Engineering

***Liberal Learning Course:**
Every student should take Liberal Learning Course for Semester VI. Students can take this course from the following list of Liberal Learning Courses.

Liberal Learning Courses	
Course Code	**Course Name**
LLC6011	Art of Living
LLC6012	Yoga and Meditation
LLC6013	Health and Wellness
LLC6014	Diet and Nutrition
LLC6015	Personality Development

Examination Scheme – TY Semester-VI

Course Code	Course Name	Examination Scheme					Total
		In-Semester Assessment$		End Sem. Exam (ESE)	Exam Duration for Theory (in Hrs)		
		Continuous Assessment	Mid-Sem Exam		Mid-Sem	End-Sem	
MEPCC611	Machine Design	20	30	50	1.5	2	100
XXMDM604	--	20	30	50	1.5	2	100
MEPEC602Y	Program Elective-II	20	30	50	1.5	2	100
MELBC609	Machine Design Laboratory	25	--	25	--	--	50
XXMDL601	--	25	--	25	--	--	50
MESBL603	CNC & 3D Printing Laboratory	50	--	50	--	--	100
MEMNP604	Mini Project-2B	50	--	50	--	--	100
ELC601	Research Methodology	50	--	--	--	--	50
LLC601Y	Liberal Learning Course	50	--	--	--	--	50
	Total	**310**	**90**	**300**	--	--	**700**

$Please refer to the Curriculum Book of respective departments for guidelines on in-semester assessments for both theory and laboratory courses.

D. Multidisciplinary Minor Courses Offered by the Department for the Other Program Students

Curriculum Structure for MDM Courses

Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		L	P	T	L	P	T	Total
MEMDM301	Elements of Mechanical Engineering	3	--	--	3	--	--	3
MEMDM402	CAD Modeling	3	--	--	3	--	--	3
MEMDM503	Product Design and Development	3	--	--	3	--	--	3
MEMDM604	Addivitve Manufacturing	4	--	--	4	--	--	4
MEMDL601	CAD Modeling and 3D Printing Laboratory	--	2	--	--	1	--	1
	Total	**13**	**2**	**--**	**13**	**1**	**--**	**14**

Examination Scheme for MDM Courses

Course Code	Course Name	Examination Scheme					Total
		In-Semester Assessment$		End Sem Exam (ESE)	Exam Duration for Theory (in Hrs)		
		Continuous Assessment	Mid-Sem Exam		Mid-Sem	End-Sem	
MEMDM301	Elements of Mechanical Engineering	20	30	50	1.5	2	100
MEMDM402	CAD Modeling	20	30	50	1.5	2	100
MEMDM503	Product Design and Development	20	30	50	1.5	2	100
MEMDM604	Addivitve Manufacturing	20	30	50	1.5	2	100
MEMDL601	CAD Modeling and 3D Printing Laboratory	25	--	25	--	--	50
	Total	**105**	**120**	**225**	--	--	**450**

E. Honours, Minor, and Honours in Reseach Degree Program

The Honours, Minor, and Honours in Research degree programs aim to empower students by offering specialized courses/research internships or projects in emerging fields of their interest, thus enhancing their proficiency in those areas. Students who achieve a CGPI of 7.5 or higher by the end of the fourth semester are eligible to pursue an additional 18 credits from the fifth to eighth semesters to qualify for a B. Tech degree with Honours, Minor, or Honours in Research designation. Students need to refer to the Institute level Handbook for Honours/Minor/Honours in Research Degree Programs for further details.

Course Type	Course Code	Course Name	Credits
PCC	MEPCC509	MECHANICAL VIBRATION	03

Examination Scheme					
Distribution of Marks			Exam Duration (Hrs.)		Total Marks
In-semester Assessment		End Semester Exam (ESE)			
Continuous Assessment	Mid-Semester Exam (MSE)		MSE	ESE	
20	30	50	1.5	2	100

Pre-requisite :

1. ESC101 Engineering Mechanics
2. MEPCC302 Mechanics of Solids

Program Outcomes addressed :

1. PO1: Engineering knowledge
2. PO2: Problem analysis
3. PO3: Design/Development of Solutions
4. PO4: Conduct investigations of complex problems
5. PO8: Individual and team work
6. PO9: Communication

Course Objectives:

1. To introduce fundamental concepts of vibrations, their causes, effects, and applications while developing competency in formulating and solving vibration problems using mathematical models.
2. To familiarise with the various damping mechanisms and their effects on vibratory systems.
3. To make aware of the response of single and multi-degree of freedom systems under free/forced conditions.
4. To acquaint with the principles of vibration measuring instruments and condition monitoring.

Module	Details	Hrs
	Course Introduction The Mechanical Vibrations course is crucial for ensuring the safety, efficiency, and reliability of mechanical systems. It helps engineers analyze, control, and minimize unwanted oscillations in applications like automotive, aerospace, and robotics. The subject supports predictive maintenance, reduces downtime, and enhances system performance. Emphasizing practical applications, it equips students with skills to effectively enhance system reliability and solve engineering vibration problems.	**01**
01.	**Basic Concepts of Vibration and Free Undamped Single Degree of Freedom (SDOF) Vibration System** ***Learning Objective:*** *To introduce the fundamental principles of vibrations, mathematical modeling, and analytical methods for solving free undamped single-degree-of-freedom systems.*	**6-7**

	Contents: Basic concepts of vibration: Vibration and oscillation, causes and effects of vibrations, Importance of study of vibrations, Vibration parameters - springs, mass, damper, Motion- periodic, non-periodic, degree of freedom, static equilibrium position, vibration classification, steps involved in vibration analysis Free Undamped Single Degree of Freedom Vibration System: Longitudinal, transverse, torsional vibration system, Methods for formulation of differential equations by Newton, Energy, Lagrangian and Rayleigh's method	
	Self-Learning Topics: *Vibrations impact on structures, machines, and human health.*	
	Learning Outcomes: *A learner will be able to* *LO 1.1: Draw a free-body diagram of given system using Newton's laws. (PI 1.2.1)* *LO 1.2 Apply the fundamental engineering concepts to identify the causes and effects of vibrations on mechanical systems. (PI 1.3.1)* *LO 1.3: Identify the nature of motion of the system to differentiate between deterministic and non-deterministic vibration (PI 2.1.1)* *LO 1.4: formulate mathematical model of an undamped SDOF system using appropriate mass-spring-damper parameters and gravitational law to govern the behavior of undamped SDOF system. (PI 2.3.1)* *LO 1.5: Determine the kinetic and potential energy in given mechanical system to use in Energy, Lagrangian, and Rayleigh's methods for vibration analysis. (PI 2.2.1)* *LO 1.6: Calculate natural frequencies of mechanical systems through mathematical modelling for vibration analyses. (PI 2.4.1)*	
02.	**Free Damped Single Degree of Freedom Vibration System and Equivalent Single Degree of Freedom Vibration System** ***Learning Objective:*** *To get accustomed to the effects of damping in vibration systems with viscous and colomb damping and simplify complex systems into equivalent single-degree-of-freedom models.*	**5-6**

	Contents: Free Damped Single Degree of Freedom Vibration System: Introduction to different methods of damping, effects of damping. types of damping, Free vibration response of single degree of freedom system with viscous damping: Critical damping, over damping and under damping, logarithmic decrement method, Free vibration response of single degree of freedom system with Colomb damping: Reduction of amplitude in one cycle due to coloumb damping. Equivalent Single Degree of Freedom Vibration System: Conversion of multi springs, multi masses, and multi-dampers into a single spring and damper with linear or rotational coordinate system.	
	Self-Learning Topics: *Effect of critical damping on automotive suspension systems and other devices.*	
	Learning Outcomes: *A learner will be able to* *LO 2.1: Draw a free-body diagram of given system using Newton's laws. (PI 1.2.1)* *LO 2.2: Apply fundamental engineering concepts to study the effects of damping (PI 1.3.1)* *LO 2.3: Use the logarithmic decrement method to calculate the amplitude decay in damped systems. (PI 2.1.1)* *LO 2.4: Identify key parameters and variables in engineering systems to compare viscous and Coulomb damping behaviour. (PI 2.1.2)* *LO 2.5: Convert complex multi-spring, multi-mass, and multi-damper systems into equivalent single-degree-of-freedom systems using free body digram and Newton's law/ Energy principle. (PI 2.2.1)* *LO 2.6: Identify the critical damping constant to determine, whether a system returns to equilibrium without oscillating (PI 2.1.2)* *LO 2.7: formulate a mathematical model of a damped SDOF system using mass-spring-damper parameters and Newton's law/ Energy principle to govern the damped SDOF system. (PI 2.3.1)*	
03.	**Forced Single Degree of Freedom Vibratory System and Vibration Isolation and Transmissibility** ***Learning Objective:*** *To study the response of damped forced vibration systems under different excitation conditions.*	**9-10**

	Contents: Response of a damped forced vibration under harmonic force excitation: Equation of motion, force polygon (inertia force, damping force, spring force excitation force and displacement, Magnification factor plot, and Phase angle plot Response of a damped forced vibration under rotating and reciprocating masses: Equation of motion, Amplitude plot, and Phase angle plot. Response of a damped forced vibration under the harmonic motion of the base or support: Equation of motion (absolute and relative method), Amplitude plot, and Phase angle plot Vibration Isolation and Transmissibility: Equation of motion, Force/Motion Transmissibility plot, Phase angle plot, and materials used for vibration isolation.	
	Self-Learning Topics: *Derivation of finding relative displacement due to support excitation and materials used for effective vibration isolation*	
	Learning Outcomes: *A learner will be able to* *LO 3.1: Apply fundamental engineering concepts to identify the forces acting on a vibrating system (PI 1.2.1)* *LO 3.2: Identify an appropriate material for effective vibration isolation based on system requirements. (PI 1.3.1)* *LO 3.3: Calculate the amplitude response of systems under different excitation types through mathematical modelling for vibration analyses. (PI 2.4.1)* *LO 3.4: Draw force polygons to illustrate the contributions of inertia, damping, spring, and excitation forces in a vibrating system. (PI 2.1.4)* *LO 3.5: Apply a relation between force/motion transmissibility and frequency ratio to identify the mass, spring, and damper-controlled region (PI 2.2.2)* *LO 3.6: Develop the mathematical model and equation of motion for a system subjected to harmonic base motion using either the absolute or relative method, demonstrating a diverse set of solutions. (PI 2.2.3)* *LO 3.7: Formulate a mathematical model of the SDOF system using mass-spring-damper parameters and Newton's law to govern the SDOF system under forced excitation. (PI 2.3.1)*	
04.	**Two Degree of Freedom System.** ***Learning Objective:*** *To study the response of two degrees of freedom system under various conditions.*	**9-10**

	Contents: System with Two Degrees of Freedom: principle mode of vibration, Normal mode, co-ordinate coupling (displacement coupling, elastic coupling velocity coupling and inertia coupling), generalized and principle co-ordinates. Natural frequency of undamped systems: Simple spring-mass systems, mass on tightly stretched strings, double pendulum, torsional systems, combined rectilinear and angular system, geared systems. The ratio of amplitude of motion, modal vector, modal shape, and location of node, Undamped forced vibrations of two degrees of freedom system with harmonic excitation, Undamped dynamic vibration absorber: Working principle, Amplitude ratio, frequency ratio, frequency ration curves	
	Self-Learning Topics: *Use of dynamic absorbers in engineering systems.*	
	Learning Outcomes: *A learner will be able to* *LO 4.1: Draw a free-body diagram of given system using Newton's laws. (PI 1.2.1)* *LO 4.2: Apply the concept of generalized coordinates in vibration analysis to obtain an uncoupled equation. (PI 1.3.1)* *LO 4.3: Apply mechanical engineering concepts to solve forced vibration problems in two-degree-of-freedom systems subjected to harmonic excitation. (PI 1.4.1)* *LO 4.4: Draw the mode shape diagram and locate node points of the system to analyze relative displacement of all parts of a system for that particular mode. (PI 2.1.4)* *LO 4.5: Formulate a mathematical model of the two degrees of freedom system using mass-spring-damper parameters and Newton's law to govern the system's various conditions. (PI 2.3.1)* *LO 4.6: Calculate natural frequencies of mechanical systems through mathematical modelling for vibration analyses. (PI 2.4.1)*	
05.	**Vibration measuring instruments, Data Acquisition & Signal Processing.** ***Learning Objective:*** *To educate on working principle of vibration measuring instruments, data acquisition, signal processing techniques and ISO standards used in vibration measurement for vibration analysis.*	**06-07**

Contents:

Vibration Measuring Instruments:
Eddy current probes, Capacitive and Inductive sensors, Seismic velocity transducers (Moving coil and Moving magnet), Laser vibrometer Piezoelectric accelerometers, MEMS accelerometers

Selection criteria of vibration measuring instrument: Frequency, Amplitude, Application Type, and Fault Detection Accuracy.

Sensor Location for Vibration Measurement: Identification of Critical Measurement Points (Bearings, Rotors, Shafts, and Machine Casings), Mode Shapes, and Node Points Consideration. Effects of Structural Rigidity and Resonance on Placement.

Sensor Mounting Techniques: Direct vs. Indirect Mounting, Mounting Methods: Stud Mounting, Adhesive Mounting, Magnetic Mounting, Handheld Probes. Effects of Mounting Stiffness on Measurement Accuracy, Preloading and Torque Considerations for Stud Mounting, and Damping Effects of Adhesive and Soft Mounting Materials.

Classification of signals: Signal analysis, Fast Fourier Transform (FFT), Essential Settings in Data Acquisition System (Plot Formats, Frequency Span and Frequency Resolution, Average Types and Number of Averages, Windowing, Spectrum Scaling), Signal conditioning.

ISO 2954:2012 -Vibration Monitoring – Characteristics of Vibration Meters,
ISO 5348:1998 – Mechanical Vibration and Shock – Mechanical Mounting of Accelerometers,
ISO 18431 Series – Signal Processing for Vibration and Shock Data,
ISO 16063 Series – Methods for the Calibration of Vibration and Shock Transducers and
ISO 5349-1 & ISO 5349-2 – Measurement and Evaluation of Human Exposure to Hand-Transmitted Vibration

Self-Learning Topics:
Introduction to ISO standards.

Learning Outcomes:
A learner will be able to

LO 5.1: Apply fundamental engineering concepts to explain the operation of vibrometer and acclerometer. (PI 1.3.1)

LO 5.2: Apply laser-based measurement techniques to determine vibration characteristics using a laser vibrometer. (PI 1.4.1)

LO 5.3: Identify key factors influencing sensor selection for vibration analysis. (PI 2.1.2)

LO 5.4: Identify suitable sensor and mounting techniques for vibration measurement based on system requirements. (PI 2.2.4)

	LO 5..5 Extract engineering requirements from ISO 16063 for transducer calibration and ISO 5349 for human vibration exposure assessment.(3.1.4) *LO 5.6: Demonstrate teamwork and technical communication skills by conducting literature reviews, analysing case studies, and presenting findings on vibration measurement techniques through well-structured reports and presentations. (P.I. 1.4.1,2.1.2,2.2.2,3.1.1, 4.1.1,4.1.2, 8.2.1, and 9.1.1)* *Each group (maximum of 4 students) will conduct a structured study on advanced vibration measurement techniques, analyzing instrument selection, sensor placement, and signal processing techniques. The task involves literature review, case study analysis, and presentation, covering the following aspects:* 1. *Instrument Identification, Comparison and Selection* 2. *Sensor Placement* 3. *Mounting Techniques* 4. *Data collection and analysis* 5. *Measurement Accuracy Evaluation* 6. *Advanced Vibration Measurement technique: Machine learning and IoT & AI-Based Vibration Monitoring System. ISO-Based Standards and Compliance in Vibration Monitoring System.*	
06.	**Introduction to Condition Monitoring and Fault detection:** ***Learning Objective:*** *To equip with knowledge of vibration based condition monitoring, fault detection, and ISO standards for machine condition assessment.* Contents: Condition monitoring, Condition monitoring techniques: Monitoring of machine and process parameters, Temperature monitoring, Lubricant monitoring, Leak detection monitoring, Noise monitoring, Acoustic emission monitoring, and Vibration monitoring Different stages of Vibration measurement and monitoring: Machine installation and commissioning, machine operation, and Aged machine. Vibration-based detection of different faults in machines: Types of faults (Rotor faults, Bearing, Gear-box faults and Motor faults. Rotor fault detection: mass unbalance, shaft bent or bow, misalignment, crack, shaft rub, etc Other fault detection: Mechanical Looseness, Blade Passing Frequency, Blade variation and Blade Health Monitoring and Electric motor defects (General electric problem, stator winding defects and rotor defects.) Bearing fault detection: Inner race, outer race, Ball and Cage defects Applications of Condition Monitoring Case studies related Balancing Problems in Turbines, Condition Monitoring in Sugar mills, Health Monitoring of Journal Bearing, Condition Monitoring of Industrial Pumps. (Aspects to be covered: Selection of sensors, recommended	**6-7**

	location of sensor, direction of measurement, selection of plot type, Data validation, and Identification of Faults) Introduction to Vibration severity charts, ISO standards; ISO 13373 Series-Covers vibration-based condition monitoring and fault diagnosis. ISO 20816 -Bearing and Shaft Vibration (merge of ISO 7919 and ISO 10816)	
	Self-Learning Topics: *ISO standards.*	
	Learning Outcomes: *A learner will be able to* *LO 6.1: Apply the principles and applications of vibration monitoring techniques in condition monitoring. (PI 1.3.1)* *LO 6.2: Identify system parameters and fault indicators for vibration-based fault detection in machines, including rotor, bearing, gearbox, and motor faults, ensuring accurate assessment and problem-solving. (P.I. 2.1.2)* *LO 6.3: Identify and analyze temperature, lubricant properties, acoustic emissions, and vibration data to select appropriate condition monitoring techniques for vibration analysis. (PI 2.2.2)* *LO 6.3: Extract engineering requirements from ISO standard 20186 guidelines to monitor vibration severity levels in rotating machinery. (PI 3.1.4)* *LO 6.5: Demonstrate teamwork and effective communication by conducting literature reviews and case study analyses on condition monitoring techniques, ensuring structured problem-solving and well-documented findings. (P.I. 1.4.1,2.1.2,2.2.2,3.1.1, 4.1.1,4.1.2, 8.2.1, and 9.1.1)* *Each group (maximum of 4 students) will conduct a structured study on vibration-based condition monitoring, analyzing fault detection techniques, machine health assessment, and compliance with ISO standards. The task involves literature review, case study analysis, and presentation, covering the following aspects:* 1. *Condition Monitoring Techniques: Identification, Comparison, and Selection* 2. *Sensor Selection and Placement for Condition Monitoring* 3. *Fault Detection and Diagnosis Techniques* 4. *Data Collection, Processing, and Validation* 5. *Measurement Accuracy Evaluation in Fault Diagnosis* 6. *Advanced Vibration Monitoring Techniques: IoT & AI-Based Fault Detection* 7. *ISO-Based Standards and Compliance in Condition Monitoring*	
	Course Conclusion:	**01**
	Total	**45**

Performance Indicators:

P.I. No.	P.I. Statement
1.2.1	Apply laws of natural science to an engineering problem
1.3.1	Apply fundamental engineering concepts to solve engineering problems
1.4.1	Apply fundamental engineering concepts to solve engineering problems
2.1.1	Articulate problem statements and identify objectives
2.1.2	Identify engineering systems, variables, and parameters to solve the problems
2.1.4 (new PI)	Desired inferences need to be drawn from graphical tools/representations of engineering quantities of mechanisms.
2.2.1	Reframe complex problems into interconnected sub-problems
2.2.2	Identify, assemble and evaluate information and resources.
2.2.3	Identify existing processes/solution methods for solving the problem, including forming justified approximations and assumptions
2.2.4	Compare and contrast alternative solution processes to select the best process.
2.3.1	Combine scientific principles and engineering concepts to formulate model/s (mathematical or otherwise) of a system or process that is appropriate in terms of applicability and required accuracy
2.4.1	Apply engineering mathematics and computations to solve mathematical models
2.4.4	Extract desired understanding and conclusions consistent with objectives and limitations of the analysis
3.1.1	Recognize that need analysis is key to good problem definition
3.1.4	Extract engineering requirements from relevant engineering Codes and Standards such as ASME, ASTM, BIS, ISO and ASHRAE.
4.1.1	Define a problem, its scope and importance for purposes of investigation
4.1.2	Examine the relevant methods, tools and techniques of experiment design, system calibration, data acquisition, analysis and presentation
8.2.1	Demonstrate effective communication, problem-solving, conflict resolution and leadership skills
9.1.1	Read, understand and interpret technical and non-technical information

Course Outcomes: A learner will be able to

1. Formulate and analyze single-degree-of-freedom vibration systems for engineering applications. (*LO 1.1, LO 1.2, LO 1.4, LO 1.5, LO 1.6, LO 2.1, LO 2.2, LO 2.3, LO 2.4, LO 2.5 LO 2.6 and LO 2.7)*
2. Evaluate the dynamic response of forced vibration systems under different excitation conditions. *(LO 3.1, LO 3.2, LO 3.3, LO 3.4, LO 3.5, LO 3.6 and LO 3.7)*
3. Apply the principles of two-degree-of-freedom systems to solve engineering vibration problems. *(LO 4.1, LO 4.2, LO 4.3, LO 4.4, LO 4.5 and LO 4.7)*

4. Use appropriate vibration measurement techniques for accurate assessment of dynamic systems. *(LO 5.1, LO 5.2, LO 5.3, LO 5.4, LO 5.5, and LO 5.6)*
5. Apply vibration monitoring and fault detection techniques to detect early-stage faults in machines *(LO 6.1, LO 6.2, LO 6.3, LO 6.4, and LO 6.5)*

CO-PO Mapping Table with Correlation Level

CO ID	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MEPCC509.1	3	3	--	--	--	--	--	--	--	--	--
MEPCC509.2	3	3	--	--	--	--	--	--	--	--	--
MEPCC509.3	2	3	--	--	--	--	--	--	--	--	--
MEPCC509.4	3	3	--	--	--	--	--	--	--	--	--
MEPCC509.5	3	3	3	3	--	--	--	2	2	--	--
MEPCC509.6	3	3	3	3	--	--	--	2	2	--	--
Average	**3**	**3**	**3**	**3**	**--**	**--**	**--**	**2**	**2**	**--**	**--**

NOTE: CO can be mapped to PO at level 3 if at least two PIs are associated with that CO; otherwise, it can be mapped at level 2.

Text Books :

1. Mechanical Vibrations, V.P. Singh, 3rd edition, 2014, Dhanpat Rai & Co.
2. Mechanical Vibrations, S.S. Rao, 6th edition, 2017, Pearson Education.
3. Theory of vibrations with applications, William T. Thomson, Marie Dillon Dahleh,and Chandramouli P. ,5th edition, 2020, Pearson Education.
4. Mechanical Vibrations, J.B. K. Das, 2nd edition, 2012, Cengage Learning.
5. Fundamentals of Vibrations, Leonard Meirovitch, 1st edition, 2001, McGraw Hill
6. B.K.N. Rao, “Handbook of Condition Monitoring”, Elsevier
7. A.R. Mohanty, “Machine Condition Monitoring: Principles and Practices”, CRC Press 2017, ISBN:9781138748255

Reference Books :

1. Mechanical Vibrations- Schaum's outline series, William W.Seto, McGraw Hill
2. Fundamentals of Mechanical Vibration by S.Graham Kelly, Tata McGraw Hll
3. Theory and Practice of Mechanical Vibrations by J.S.Rao, K. Gupta, New Age International Publications
4. R.A. Collacott, “Mechanical Fault Diagnosis and Condition Monitoring”,1st Edition, Chapman and Hall, ISBN: 978-94-009-5723-7

Other Resources :

1. NPTEL Course: Vibration Analysis and Control by Prof. R. R. Rajput, Department of Mechanical Engineering at IIT Delhi:
   Web Link: https://nptel.ac.in/courses/112106039

2. NPTEL Course: Dynamics of Machines by Prof. C. Amarnath, Prof. K. Kurien Issac, and Prof. P. SeshuDepartment of Mechanical Engineering at IIT Bombay:
Web lnk- https://nptel.ac.in/courses/112/101/112101096/:

3. ttps://nptel.ac.in/courses/112105232 – Machinery Fault Diagnosis and Signal Processing, IIT, Kharagpur

IN-SEMESTER ASSESSMENT (50 MARKS)

1. Continuous Assessment - Theory-(20 Marks)

Suggested breakup of distribution

Tool to be used	Marks
• Numerical Assignment/s (min 20 problems)	05
• Class test based on above numerical assignment	05
• Article reading	05
• Regularity and Active Participation	05

2. Mid Semester Exam (30 Marks)

Mid semester examination will be based on 40% to 50% syllabus.

END SEMESTER EXAMINATION (50 MARKS)

End Semester Examination will be based on syllabus coverage up to the Mid Semester Examination (MSE) carrying 20%-30% weightage, and the syllabus covered from MSE to ESE carrying 70%-80% weightage.

Course Type	Course Code	Course Name	Credits
PCC	MEPCC510	FLUID MECHANICS AND MACHINERY	03

Examination Scheme					
Distribution of Marks			Exam Duration (Hrs.)		Total Marks
In-semester Assessment		End Semester Examination (ESE)			
Continuous Assessment	Mid-Semester Exam (MSE)		MSE	ESE	
20	30	50	1.5	2	100

Pre-requisite:

1. ESC101 Engineering Mechanics
2. MEPCC301 Engineering Mathematics-III
3. MEPCC407 Thermal Engineering

Program Outcomes addressed:

1. PO1: Engineering knowledge
2. PO2: Problem analysis
3. PO5: Engineering Tool Usage
4. PO8: Individual and Collaborative Team work
5. PO9: Communication

Course Objectives:

1. To acquire knowledge of core fluid mechanics principles, including viscosity, fluid statics, and Archimedes principle, showcasing adept application proficiency.
2. To develop skills for applying fluid kinematics and dynamics, analysing viscous flow, and solving practical problems in hydraulic turbines, pumps, and pumping systems.
3. To apply theoretical knowledge practically, showcasing expertise in using Bernoulli's equation for devices like orifice meters and Venturi meters, and analysing thrust in pipe bends.
4. To develop problem-solving skills for real-world engineering challenges, emphasizing practical application.
5. To understand and quantify different types of losses in pipes and turbomachinery.

Module	Details	Hrs.
	Course Introduction This course introduces the principles of fluid mechanics and their application to fluid machinery. It covers fluid behavior, including flow dynamics, energy transformation, and key concepts like Bernoulli's and continuity equations. Students will also learn about the design, operation, and performance of fluid machinery such as pumps, turbines, and compressors. The course combines theoretical understanding with	**01**

	practical problem-solving, preparing students to analyze and optimize fluid systems in real-world engineering applications.	
01.	**Introduction** ***Learning Objective:*** *To utilize the knowledge of fluid statics and its properties to quantify hydrostatic forces acting over submerged surfaces.* **Contents:** Newton's law of viscosity, Newtonian and non-Newtonian Fluid, Fluid Statics: Pascal's law, Hydrostatic law, hydrostatic force on submerged surfaces (horizontal, vertical, inclined & curved), Archimedes principle, Buoyancy and Floatation. ***Self-Learning Topics:*** *Different types of fluids, Fluid properties* ***Learning Outcomes:*** *A learner will be able to* *LO 1.1: Apply Newton's law of viscosity to characterize the behavior of Newtonian and non-Newtonian fluids, understanding the relationship between shear stress and shear rate. (P.I.-1.3.1)* *LO 1.2: Apply fluid statics principles to analyze and calculate hydrostatic forces on Pascal's submerged surfaces. (P.I.-1.4.1)* *LO 1.3: Employ Archimedes' Principle to determine buoyancy and flotation forces acting on submerged or floating bodies. (P.I.-2.1.2)* *LO 1.4: Derive and apply the concepts of buoyancy and flotation in practical engineering problems, including the calculation of forces and equilibrium conditions. (P.I.-2.3.1)*	**7-9**
02.	**Fluid Kinematics** ***Learning Objective:*** *To leverage the differential equation of continuity to analyze fluid kinematics and evaluate mathematical models to understand various fluid patterns.* **Contents:** Classification of fluid flow, streamline, path line, streak line, acceleration of fluid particle, local and convective acceleration, differential equation of continuity, concept of circulation, rotational flow and vortices, stream function and potential function. Methods of dimensional analysis - Buckingham π Theorem and Rayleigh's Method. ***Self-Learning Topics:*** *Cauchy Riemann Equation* ***Learning Outcomes:*** *A learner will be able to* *LO 2.1: Apply mechanical engineering concepts to classify fluid flow into different types (steady, unsteady, laminar, turbulent) and distinguish between streamlines, path lines, and streaklines. (PI-1.4.1)* *LO 2.2: Apply fundamental engineering concepts to distinguishing between acceleration of fluid flow, local and convective acceleration. (PI-1.3.1)*	**7-9**

	LO 2.3: Derive and apply the differential equation of continuity to fluid flow problems (PI-2.1.3) *LO 2.4: Apply dimensional analysis techniques such as Buckingham π Theorem and Rayleigh's Method to derive dimensionless groups and empirical relationships for fluid flow problems. (PI- 2.3.1)*	
03.	**Dynamics of Fluid Flow**	**7-9**
	Learning Objective: *To employ Bernoulli's principle to practical fluid flow problems and analyze flow with control volume approach using RTT.*	
	Contents: Concept of control volume and control surface, Importance of Reynolds Transport theorem (RTT) and its derivation (No numerical), Forces acting on fluid in motion, Euler's equation in Cartesian coordinates, Expression of Bernoulli's equation from principle of energy conservation and by integration of Euler's equation. Application of Bernoulli's equation in Orifice meter, Venturi meter and Pitot tube. Momentum of fluid in motion: impulse momentum relationship and its applications for determination of thrust for pipe bend.	
	Self-Learning Topics: *Working principle of rotameter.*	
	Learning Outcomes: *A learner will be able to* *LO 3.1: Discuss the importance of the Reynolds Transport Theorem (RTT) and describe its role in converting a system description to a control volume description. (PI-1.3.1)* *LO 3.2: Conceptually define control volume and control surface and explain their significance in fluid mechanics. (PI- 1.4.1)* *LO 3.3: Analyze and explain the forces acting on a fluid in motion using Euler's equation in Cartesian coordinates. (PI- 2.1.2)* *LO 3.4: Apply the impulse-momentum relationship **to** determine the momentum change of a fluid in motion and calculate the resulting thrust in systems like pipe bends. (PI-2.3.1)* *LO 3.5: Apply fundamental and mechanical engineering knowledge to set up, run, and analyze Computational Fluid Dynamics (CFD) simulations to model fluid flow through a pipe, interpret key flow characteristics such as velocity, pressure, and turbulence, and compare the results with theoretical predictions and real-world data to assess the accuracy and performance of the model. (PI:.1.3.1, PI:.1.4.1, PI:.2.2.4, PI:.2.4.2, PI:.5.1.1, PI:.5.2.1, PI: 9.1.2, PI: 9.1.3)*	
04.	**Flows in Conduits**	**6-8**
	Learning Objectives: 1. *To harness the knowledge of Bernoulli's and Darcy-Weisbach equation to calculate head losses in fluid flow systems.* 2. *To categories different flow regime and analyse forces acting on fluid for different geometries.*	
	Contents: Head loss in pipes due to friction (Darcy-Weisbach equation), Loss of energy in pipe (major and minor). Relationship between shear stress and pressure gradient in laminar flow, Laminar flow between parallel plates (Plane	

	Poiseuille & Couette flow), Laminar flow in circular pipe (Hagen-Poiseuille flow).	
	Self-Learning Topics: *Relationship between shear stress and pressure gradient in laminar flow*	
	Learning Outcomes:	
	A learner will be able to *LO 4.1: Apply fundamental engineering knowledge to determine head losses in pipes using the Darcy-Weisbach equation. (PI-1.3.1)* *LO 4.2: Identify and evaluate major and minor energy losses within piping system and apply this knowledge to assess fluid system performance. (PI-2.1.2)* *LO 4.3: Compare various geometries in laminar flow, illustrate velocity profiles for fluid flows. (PI-1.4.1)* *LO 4.4: Employ the concepts of shear stress and pressure gradient in laminar flow to analyze and address engineering challenges efficiently. (PI-2.4.1)*	
05.	**Hydraulic Turbine** ***Learning Objective/s:*** *To utilise the knowledge of hydraulic turbines to estimate it's performance.*	**5-7**
	Contents: Hydraulic Turbine: Basic theory, Classification of turbines, Theory of impulse and reaction turbines, Characteristics of turbines, Specific speed of turbine, Types of pumps: Pelton turbine, Francis turbine, Kaplan turbine.	
	Self-Learning Topics: *Classification of modern turbines.*	
	Learning Outcomes :	
	A learner will be able to *LO 5.1: Apply mechanical engineering concepts to describe the characteristics of turbines in terms of efficiency, flow rates, and power output. (PI-1.4.1)* *LO 5.2: Apply fundamental engineering concepts to Describe the basic theory of hydraulic turbines, including the principles of energy conversion from fluid flow to mechanical energy. (PI-1.3.1)* *LO 5.3: Demonstrate understanding of impulse and reaction turbine principles and recognize their respective characteristics. (PI-2.1.3)* *LO 5.4: Analyze hydraulic turbine systems, for optimal performance based on construction and operational factors. (PI-2.4.1)*	
06.	**Hydraulic Pumps**	**5-7**
	Learning Objective/s: *To utilise the knowledge of hydraulic pumps to estimate it's performance.*	
	Contents: Classification of pumps, Definition of pumping systems and system characteristics, Specific speed of pumps, Centrifugal pumps: Construction, characteristics, determination of operating point, cavitation and NPSH. Reciprocating pumps: Construction, Types, Discharge, head, efficiency of pump and Use of Air vessel.	

	Self-Learning Topics: *Classification of modern pumps* ***Learning Outcomes:*** *A learner will be able to* *LO 6.1: Apply mechanical engineering concepts to describe the characteristics of pumps in terms of efficiency, flow rates, and power output. (PI-1.4.1)* *LO 6.2: Apply fundamental engineering concepts to describe the basic theory of hydraulic pumps, including the principles of energy conversion from mechanical energy to fluid flow (PI- 1.3.1)* *LO 6.3: Analyze hydraulic pump systems, including centrifugal pump and reciprocating pump, for optimal performance based on construction and operational factors. (PI-2.4.1)* *LO 6.4: Select the appropriate pump size, apply problem-solving techniques, collaborate with the team, present outcomes confidently, and create clear, professional engineering drawings. (PI-2.1.2, PI-8.2.1, PI-8.2.2, PI-9.1.2, PI-9.3.1)*	
	Course Conclusion	**01**
	Total	**45**

Performance Indicators:

P.I. No.	**P.I. Statement**
1.3.1	Apply fundamental engineering concepts to solve engineering problems.
1.4.1	Apply Mechanical engineering concepts to solve engineering problems.
2.1.2	Identify engineering systems, variables, and parameters to solve the problems.
2.1.3	Identify the mathematical, engineering and other relevant knowledge that applies to a given problem.
2.2.4	Compare and contrast alternative solution processes to select the best process.
2.3.1	Combine scientific principles and engineering concepts to formulate model/s (mathematical or otherwise) of a system or process that is appropriate in terms of applicability and required accuracy.
2.4.1	Apply engineering mathematics and computations to solve mathematical models.
2.4.2	Produce and validate results through skilful use of contemporary engineering tools and models.
5.1.1	Identify modern engineering tools such as computer-aided drafting, modeling and analysis; techniques and resources for engineering activities.
5.2.1	Identify the strengths and limitations of tools for (i) acquiring information, (ii) modeling and simulating, (iii) monitoring system performance, and (iv) creating engineering designs.
8.2.1	Demonstrate effective communication, problem-solving, conflict resolution and leadership skills.
8.2.2	Treat other team members respectfully.
9.1.2	Produce clear, well-constructed, and well-supported written engineering documents.
9.1.3	Create flow in a document or presentation - a logical progression of ideas so that the main point is clear.
9.3.1	Create engineering-standard figures, reports and drawings to complement writing and presentations.

Course Outcomes: A learner will be able to -

1. Apply the basic concepts of fluid mechanics to determine viscous effects of fluid and hydrostatic forces. (*LO 1.1, LO 1.2, LO 1.3, LO 1.4)*
2. Apply the concepts of fluid kinematics and visualize the fluid flow using mathematical models. (*LO 2.1, LO 2.2, LO 2.3, LO2.4)*
3. Apply laws of mass, momentum and energy conservation in fluid dynamics. (*LO 3.1, LO 3.2, LO 3.3, LO 3.4)*
4. Apply engineering knowledge to analyze CFD simulations for real-time applications and select the appropriate pump size for the given problem, while collaborating with the team and presenting results clearly with professional drawings. *(LO 3.5, LO 6.4)*
5. Apply knowledge to determine losses in pipe, shear stress and pressure gradient in laminar flow. (*LO 4.1, LO 4.2, LO 4.3, LO 4.4)*
6. Apply knowledge to determine performance parameters of hydraulic machines. (*LO 5.1, LO 5.2, LO 5.3, LO 5.4, LO 6.1, LO 6.2, LO 6.3)*

CO-PO Mapping Table with Correlation Level

CO ID	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MEPCC510.1	3	3	--	--	--	--	--	--	--	--	--
MEPCC510.2	3	3	--	--	--	--	--	--	--	--	--
MEPCC510.3	3	3	--	--	--	--	--	--	--	--	--
MEPCC510.4	3	3	--	--	3	--	--	3	3	--	--
MEPCC510.5	3	3	--	--	--	--	--	--	--	--	--
MEPCC510.6	3	3	--	--	--	--	--	--	--	--	--
Average	**3**	**3**	--	--	**3**	--	--	**3**	**3**	--	--

NOTE: CO can be mapped to PO at level 3 if at least two PIs are associated with that CO; otherwise, it can be mapped at level 2.

Text Books :

1. A textbook of Fluid Mechanics by R K Bansal, 1st Edition, 2015, Laxmi Publication
2. Engineering Fluid Mechanics by K. L. Kumar: 1st Edition, and reprint 2016, Eurasia Publishing house (P) Ltd.
3. Fluid Mechanics and Machinery by C S P Ojha, Chandramaouli, and R Berndtson, 1st Edition, 2010, Oxford University Press India
4. A Textbook of Fluid Mechanics and Hydraulic Machines by R K Rajput, 6th Edition, 2016, S. Chand.

Reference Books :

1. Fluid Mechanics by Yunus A Cengel and John A Cimbala, 3rh Editiion, 2014, Tata McGraw-Hill

2. Fluid Mechanics by Frank M. White, by, 7th edition, 2011, McGraw-Hill Education

3. Fluid Mechanics by Kundu and Cohen, , by, 6th Edition, 2016, Elsevier Inc.

4. Hydraulics and Fluid Mechanics by Dr. Mody and Seth, 21st Edition, 2017, Standard book house.

Other Resources :

1. NPTEL Course: Introduction to Fluid Mechanics By Prof. Suman Chakraborty, Department of Mechanical Engineering at IIT Kharagpur:
   Web link- https://nptel.ac.in/courses/112/105/112105269
2. NPTEL Course: Fluid Mechanics by Prof. Subashisa Datta, Department of Mechanical Engineering, IIT Guwahati: Web link: http://swayam.gov.in/nd1_noc20_ce59/preview
3. NPTEL Course: Introduction to Turbo Machines by Prof. Babu Viswanathan, Department of Mechanical Engineering at IIT Madras: Web link: https://nptel.ac.in/courses/112/106/112106303/

IN-SEMESTER ASSESSMENT (50 MARKS)

1. Continuous Assessment - Theory-(20 Marks)

Suggested breakup of distribution

MCQ test as per GATE pattern/level	:	05 marks
Class test	:	05 marks
Think Pair Share worksheet	:	05 Marks
Regularity and active participation	:	05 Marks

2. Mid Semester Exam (30 Marks)

Mid semester examination will be based on 40% to 50% syllabus.

END SEMESTER EXAMINATION (50 MARKS)

End Semester Examination will be based on syllabus coverage up to the Mid Semester Examination (MSE) carrying 20%-30% weightage, and the syllabus covered from MSE to ESE carrying 70%-80% weightage.

Course Type	Course Code	Course Name	Credits
PEC	MEPEC5011	FINITE ELEMENT ANALYSIS	03

Examination Scheme					
Distribution of Marks			Exam Duration (Hrs.)		Total Marks
In-semester Assessment		End Semester Exam (ESE)			
Continuous Assessment	Mid-Semester Exam (MSE)		MSE	ESE	
20	30	50	1.5	2	100

Pre-requisite :

1. BSC101 - Engineering Mathematics-I
2. BSC204 - Engineering Mathematics-II
3. MEPCC301 - Engineering Mathematics-III
4. MEPCC302 - Mechanics of Solids

Program Outcomes addressed :

1. PO1: Engineering knowledge
2. PO2: Problem analysis
3. PO3: Design/Development of Solutions
4. PO4: Conduct Investigations of Complex Problems
5. PO5: Engineering Tool Usage
6. PO8: Individual and Team Work
7. PO9: Communication

Course Objectives :

1. Enable students to comprehend foundational FEA concepts, software workflows, and geometry preparation techniques for effective pre-processing.
2. Equip students with the ability to perform static structural analyses, interpret stress/strain results, and validate findings against theoretical solutions.
3. Instruct students in analysing dynamic systems through modal, harmonic, and transient analyses to identify natural frequencies and resonance risks.
4. Guide students in simulating heat transfer mechanisms and evaluating coupled thermo-mechanical effects, such as thermal expansion and stress.
5. Train students to model non-linear behaviours, including material plasticity and contact interactions, using advanced FEA software tools.
6. Prepare students to apply fatigue analysis, fracture mechanics and multi-physics simulations to refine designs and solve complex engineering problems.

Module	Details	Hrs
	Course Introduction This course equips students with the fundamental principles and practical skills of FEA, covering topics like static structural analysis, dynamic and modal analysis, thermal and thermo-mechanical analysis, and non-linear analysis. Through hands-on learning with commercial software package, students will apply FEA in real-world mechanical engineering problems. Advanced topics like design optimization and multi-physics simulations will also be explored. This comprehensive approach ensures students develop critical problem-solving skills, making them competitive and versatile in the engineering industry.	**01**
01.	**Introduction to FEA** ***Learning Objective/s:*** *To get acquainted to the history, applications, and limitations of Finite Element Analysis (FEA) and apply its workflow using industry-standard software for geometry preparation, material assignment, and meshing.*	**4-6**
	Contents: ***History, applications, and limitations.*** ***Types of analysis:*** Structural, thermal, modal, fluid, etc. Overview of FEA workflow: Pre-processing, solving, and post-processing, ***Introduction to FEA software***, Geometry preparation, Importing CAD models and simplifying geometry, Material properties and meshing: Element types, mesh quality, and convergence. ***Tool-Based Learning:*** • Create a simple 3D model and mesh it using commercial software package • Assign materials and boundary conditions to a cantilever beam	
	Self-Learning Topics: *Advanced Meshing Options and Mesh refinement*	
	Learning Outcomes : *A learner will be able to* *LO 1.1 Identify the history, applications, and limitations of Finite Element Analysis (FEA) in engineering and scientific fields. (PI 2.1.2, PI 2.3.2, PI 2.4.4)* *LO 1.2 Demonstrate an understanding of the FEA process, including pre-processing, solving, and post-processing, to conduct accurate simulations. (PI 2.2.2, PI 2.3.2, PI 2.4.3)* *LO 1.3 Perform geometry preparation, import CAD models, and simplify geometry for efficient FEA simulations. (PI 5.2.1, PI 5.1.1, PI 4.3.4)* *LO 1.4 Assign appropriate material properties and implement meshing techniques while ensuring mesh quality and convergence. (PI 2.2.4, PI 2.3.1)*	

02.	**Structural Analysis (Static and Linear)** ***Learning Objective/s:*** *To apply elasticity theory, solve linear static problems with FEA software, and optimize simulations through parametric studies and mesh refinement.*	**8-10**
	Contents: ***Theory of elasticity and stress-strain relationships*** ***Boundary Conditions and Loads:*** Forces, Pressures, and Displacements ***Element Types:*** Solid Elements, Shell Elements, Beam Elements, Tetrahedral Elements *(Different types of elements and element selection to be covered from FEA perspective.)* ***Boundary Condition Types:*** Fixed Support, Displacement Support, Frictionless Support, Cylindrical Support, Compression Only Support ***Solver Selection:*** Direct Solver, Iterative Solver *(Background theoretical knowledge related to types of solver to be discussed from FEA perspective)* ***Solver Settings:*** Damping, Large Deflection, Pivot Checking, Inertia Relief *(Basic background of solver settings to be discussed from FEA perspective)* ***Post-Processing Types***: Stress Contours, Deformation Plots, Safety Factors **Tool-Based Learning:** • Analyze a bracket or beam under static loading using commercial software package. • Conduct a parametric study by varying loads/materials in the software and evaluate their impact on stress/deformation. • Perform a mesh convergence analysis to assess how mesh density influences simulation accuracy.	
	Self-Learning Topics: --	
	Learning Outcomes : *A learner will be able to* *LO 2.1 Apply principles of elasticity theory and stress-strain relationships to define boundary conditions (force, pressure, displacement) and analyze their impact on mechanical systems. (PI 1.3.1, PI 2.3.1, PI 4.1.4, PI 5.1.2)* *LO 2.2 Apply commercial software to solve linear static problems, interpret results, and evaluate stress contours, deformation plots, and safety factors. (PI 1.1.1, PI 2.1.2, PI 5.2.1, PI 5.3.2, PI 8.1.2, PI 9.3.1)* *LO 2.3 Conduct parametric studies and mesh convergence analysis to assess the impact of load/material variations and mesh density on simulation accuracy. (PI 2.4.3, PI 5.3.2)*	
03.	**Dynamic and Modal Analysis** ***Learning Objective/s:*** *To analyze dynamic systems by determining natural frequencies and mode shapes through modal analysis and simulating transient responses and damping effects using commercial FEA software.*	**11-12**

	Contents: **Modal Analysis: Natural Frequencies and Mode Shapes** ***Element Types:*** Solid, Shell, Beam ***Boundary Conditions:*** Fixed Support, Displacement Support ***Solver***: Eigenvalue ***Solver Settings:*** Number of Modes, Frequency Range ***Post-Processing:*** Mode Shapes, Natural Frequencies **Harmonic and Transient Analysis** ***Element Types:*** Solid, Shell, Beam ***Boundary Conditions:*** Harmonic Loads, Transient Loads ***Solver:*** Harmonic Response Solver, Transient Dynamic Solver ***Solver Settings:*** Damping, Time Step, Load Frequency ***Post-Processing:*** Frequency Response Plots, Time History Plots, Stress and Deformation Contours **Damping Effects and Resonance** ***Element Types:*** Solid, Shell, Beam ***Boundary Conditions:*** Damping Support ***Solver:*** Modal Damping Analysis ***Solver Settings:*** Damping Ratios, Material Damping ***Post-Processing:*** Damped Natural Frequencies, Mode Shapes with Damping ***Tool-Based Learning:*** • Perform modal analysis on a simple structure (e.g., a cantilever beam) using commercial software package. • Simulate a transient response for a structure under impact loading.	
	Self-Learning Topics: --	
	Learning Outcomes : *A learner will be able to* *LO 3.1 Quantify natural frequencies, mode shapes, damping effects, and resonance in dynamic systems. (PI 1.4.1, PI 2.1.2, PI 4.1.3, PI 5.1.1)* *LO 3.2 Compute mode shapes and simulate harmonic and transient responses using commercial software. (PI 1.4.1, PI 2.1.2, PI 5.1.1, PI 5.2.2, PI 5.3.2)* *LO 3.3 Apply a commercial software package to perform modal and transient simulations for structures subjected to impact loading. (PI 5.1.1, PI 5.2.2, PI 8.1.2, PI 9.3.1)*	
04.	**Thermal and Thermo-Mechanical Analysis**	**6-8**
	Learning Objective/s: *To analyze heat transfer modes and coupled thermo-mechanical problems using steady-state and transient thermal analysis techniques.*	
	Contents: ***Heat Transfer Modes:*** Conduction, Convection, and Radiation ***Steady-State and Transient Thermal Analysis:*** ***Elements:*** Solid, Shell, Line ***Boundary Conditions:*** Convection, Radiation, Temperature, Heat Flux, Adiabatic ***Solver Selection:*** Steady-State, Transient Thermal	

	Solver Settings: Initial Conditions, Time Step (for Transient), Convergence Criteria ***Post-Processing:*** Temperature Contours, Heat Flux Vectors, Thermal Gradients ***Thermo-Mechanical Coupling: Thermal Stresses and Expansion*** ***Elements:*** Solid, Shell ***Boundary Conditions:*** Thermal Loads, Mechanical Loads ***Solver:*** Thermo-Mechanical ***Settings***: Temperature-Dependent Material Properties, Thermal Expansion Coefficients, Coupled Field Analysis ***Post-Processing:*** Thermal Stress Contours, Displacement Plots, Thermal Strain ***Tool-Based Learning***: • Simulate heat transfer in a heat sink using a commercial software package. • Analyze thermal stresses in a pipe under temperature gradients.	
	Self-Learning Topics: **--**	
	Learning Outcomes : *A learner will be able to* *LO 4.1 Quantify conduction, convection, and radiation in steady-state and transient conditions. (PI 1.1.1, PI 1.4.1, PI 4.1.4)* *LO 4.2 Evaluate thermal stresses through heat transfer simulations using commercial software. (PI 1.4.1, PI 5.2.2, PI 5.3.1)* *LO 4.3 Apply computational tools to model heat dissipation in a heat sink and analyze thermal stresses in a pipe under temperature gradients. (PI 5.1.1, PI 8.1.2, PI 9.3.1)*	
05.	**Non-Linear Analysis** ***Learning Objectives:*** *To analyze nonlinearities (geometric, material, contact) and simulate material models and contact mechanics using commercial software.*	**5-7**
	Contents:	
	Geometric Non-Linearity ***Elements:*** Shell, Solid, Beam ***Meshing:*** Coarse and Fine mesh, quadratic elements. ***Solver Selection:*** Newton-Raphson (implicit), Arc-Length (post-buckling), Explicit (severe deformation). ***Solver Settings:*** Automatic time stepping, adaptive convergence. ***Post-Processing:*** Deformation plots, buckling modes, energy curves. **Material Non-Linearity** ***Plasticity Models:*** Bilinear, kinematic hardening (von Mises, Drucker-Prager). ***Hyperelasticity:*** Mooney-Rivlin, Neo-Hookean, Ogden. ***Creep:*** Norton's Law, Prandtl-Reuss. ***Elements:*** Solid (plasticity, creep). ***Meshing:*** Quadratic elements, refined mesh in stress zones. ***Solver Selection:*** Static (plasticity, creep), Explicit (hyper elasticity).	

	Solver Settings: Nonlinear stabilization, time integration for creep. ***Post-Processing:*** Plastic strain contours, stress-strain curves, creep strain vs. time. **Contact Non-Linearity** ***Types:*** Frictionless, frictional (Coulomb), bonded, rough. ***Elements:*** 3D 8-node surface-to-surface contact element, 3D target segment element, 20-node brick element, 10-node tetrahedral element ***Meshing:*** Refined contact zones, matching mesh for accuracy. ***Solver Selection:*** Penalty method, Augmented Lagrange, Lagrange multipliers ***Solver Settings:*** Frictional sliding, contact stiffness adjustment, stabilization damping. ***Post-Processing:*** Contact pressure, frictional stress, slip visualization, reaction forces. ***Tool-Based Learning:*** • Simulate a rubber component under large deformation using commercial software package. • Analyze contact between two metal parts under load.	
	Self-Learning Topics: --	
	Learning Outcomes : *A learner will be able to* *LO 5.1 Identify geometric, material, and contact nonlinearities in structural systems. (PI 2.1.2, PI 2.3.1, PI 5.2.1, PI 5.3.1)* *LO 5.2 Perform nonlinear simulations covering plasticity, hyper elasticity, and creep in materials using commercial software. (PI 2.4.1, PI 2.4.2, PI 5.1.2, PI 5.2.2)* *LO 5.3 Simulate large deformations in rubber components. (PI 2.2.3, PI 2.4.2, PI 5.2.1, PI 5.3.2)* *LO 5.4 Analyze contact mechanics in metal parts under load.(PI 2.3.1, PI 2.4.4, PI 4.1.3, PI 5.2.2, PI 9.3.1)*	
06.	**Fatigue Analysis, Fracture Mechanics and Multi-Physics Simulations**	**5-7**
	Learning Objective/s: *To comprehend and apply advanced finite element techniques in ANSYS for fatigue analysis, fracture mechanics, and multi-physics simulations, including appropriate element selection, meshing strategies, solver configurations, and post-processing methods to ensure accurate and efficient simulations.*	
	Contents:	
	Fatigue Analysis ***Element Types:*** Quadratic elements, Surface-coating elements. ***Meshing:*** High-density meshes at stress concentrators (notches, holes), Cyclic symmetry meshing for rotational components. **Solver Selection**: Implicit solvers for low-cycle fatigue, Explicit solvers with cycle-jumping for high-cycle fatigue. **Solver Settings**: Rainflow counting integration, SN/EN curves with Goodman correction. **Post-Processing**: Fatigue life contour plots (Miner's rule), Critical node	

	tracking for crack initiation. ***Fracture Mechanics*** ***Element Types***: Quarter-point elements, Cohesive zone elements ***Meshing:*** Spider-web meshing, XFEM (eXtended Finite Element Method) ***Solver Selection:*** Static implicit, Explicit dynamic ***Solver Settings:*** Contour integral settings ***Post-Processing:*** Crack path visualization, Stress intensity factor (SIF) history plots. **Multi-Physics Simulations (Fluid-Structure Interaction)** ***Element Types:*** Lagrangian shells/solids for structures; Eulerian tetrahedral/hexahedral for fluids**,** Interface for coupling. ***Meshing:*** Non-conformal meshes, Arbitrary Lagrangian-Eulerian (ALE). ***Solver Selection:*** Partitioned coupling, Monolithic solvers ***Solver Settings:*** Under-relaxation factors, Time-step sub-cycling ***Post-Processing:*** Fluid pressure/stress overlays on deformed structures, Streamlines with displacement animations. ***Tool-Based Learning:*** • Perform the fatigue analysis of a metallic plate with a central hole subjected to cyclic loading, leading to potential fatigue failure. • Conduct fracture mechanics analysis for a pre-cracked structural component subjected to external loading, raising concerns about crack growth and structural integrity. • Perform a fluid-structure interaction (FSI) simulation of a flexible plate subjected to fluid flow, leading to structural deformation due to fluid forces in order to ensure structural stability.	
	Self-Learning Topics: --	
	Learning Outcomes : *A learner will be able to* *LO 6.1 To perform fatigue analysis and interpret fatigue life contour plots in order to identify critical regions for failure prevention. (PI 2.4.2, PI 5.1.1, PI 5.2.1)* *LO 6.2 To analyze fracture mechanics to assess structural durability. (PI 2.4.3, PI 4.1.3, PI 4.3.1, PI 5.2.2)* *LO 6.3 To perform multi-physics simulations and validate FEA results using industry software. (PI 2.3.1, PI PI 2.4.2, PI 5.1.2, PI 5.3.1, PI 5.3.2, PI 8.1.2, PI 9.3.1)*	
	Course Conclusion	**01**
	Total	**45**

Performance Indicators:

P.I. No.	P.I. Statement
1.1.1	Apply mathematical techniques such as calculus, linear algebra, and statistics to solve problems
1.3.1	Apply fundamental engineering concepts to solve engineering problems.
1.4.1	Apply mechanical engineering concepts to solve engineering problems.
2.1.2	Identify engineering systems, variables, and parameters to solve the problems.
2.2.2	Identify, assemble, and evaluate information and resources.
2.2.3	Identify existing processes/solution methods for solving the problem, including forming justified approximations and assumptions.
2.2.4	Compare and contrast alternative solution processes to select the best process.
2.3.1	Combine scientific principles and engineering concepts to formulate models (mathematical or otherwise) of a system or process that is appropriate in terms of applicability and required accuracy.
2.3.2	Identify assumptions (mathematical and physical) necessary to allow modeling of a system at the level of accuracy required.
2.4.1	Apply engineering mathematics and computations to solve mathematical models.
2.4.2	Produce and validate results through skillful use of contemporary engineering tools and models.
2.4.3	Identify sources of error in the solution process and limitations of the solution.
2.4.4	Extract desired understanding and conclusions consistent with objectives and limitations of the analysis.
4.1.3	Apply appropriate instrumentation and/or software tools to make measurements of physical quantities.
4.1.4	Establish a relationship between measured data and underlying physical principles.
4.3.1	Use appropriate procedures, tools, and techniques to conduct experiments and collect data.
4.3.4	Synthesize information and knowledge about the problem from the raw data to reach appropriate conclusions.
5.1.1	Identify modern engineering tools such as computer-aided drafting, modeling, and analysis; techniques and resources for engineering activities.
5.1.2	Create/adapt/modify/extend tools and techniques to solve engineering problems.
5.2.1	Identify the strengths and limitations of tools for (i) acquiring information, (ii) modeling and simulating, (iii) monitoring system performance, and (iv) creating engineering designs.
5.2.2	Demonstrate proficiency in using discipline-specific tools.
5.3.1	Discuss limitations and validate tools, techniques, and resources.
5.3.2	Verify the credibility of results from tool use with reference to the accuracy and limitations, and the assumptions inherent in their use.
8.1.2	Implement the norms of practice (e.g., rules, roles, charters, agendas, etc.) of effective teamwork to accomplish a goal.
9.3.1	Create engineering-standard figures, reports, and drawings to complement writing and presentations

Course Outcomes :

1. Apply fundamental FEA concepts, including pre-processing, solving, and post-

processing, to model and analyse mechanical systems. *(LO 1.1, LO 1.2, LO 1.3, LO 1.4)*

2. Utilize commercial software to solve linear static problems, conduct parametric studies, and assess stress-strain relationships for accurate simulations. *(LO 2.1, LO 2.2, LO 2.3)*

3. Perform dynamic and thermal analyses by computing mode shapes, transient responses, and thermal stresses using industry-standard tools. *(LO 3.1, LO 3.2, LO 3.3, LO 4.1, LO 4.2, LO 4.3)*

4. Analyse nonlinear structural behaviour, including plasticity, hyper elasticity, creep, and contact mechanics, using advanced FEA techniques. *(LO 5.1, LO 5.2, LO 5.3, LO 5.4)*

5. Apply FEA techniques for fatigue, fracture, and multi-physics simulations, ensuring accurate analysis through proper meshing, solvers, and post-processing. *(LO 6.1, LO 6.2, LO 6.3)*

CO-PO Mapping Table with Correlation Level

CO ID	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MEPEC5011.1	--	3	--	2	3	--	--	--	--	--	--
MEPEC5011.2	3	3	--	2	3	--	--	2	2	--	--
MEPEC5011.3	3	3	--	2	3	--	--	2	2	--	--
MEPEC5011.4	3	--	--	2	3	--	--	2	2	--	--
MEPEC5011.5	--	3	--	2	3	--	--	--	2	--	--
Average	**3**	**3**	**--**	**2**	**3**	**--**	**--**	**2**	**2**	**--**	**--**

NOTE: CO can be mapped to PO at level 3 if at least two PIs are associated with that CO; otherwise, it can be mapped at level 2.

Text Books :

1. P. N. Godbole & Dhananjay R. Dolas , *Finite Element Method and Computational Structural Dynamics with ANSYS,* (CRC Press)
2. Kenneth G. Budinski , *Engineering Materials: Properties and Selection with ANSYS Applications*, (Prentice Hall)
3. Ram K. Jha, *ANSYS Workbench Tutorial: Structural & Thermal Analysis Using the Finite Element Method*, (CRC Press)
4. Buch A. & Hadi M., *Practical Finite Element Simulations with ANSYS Workbench 2023*, (Springer)
5. Saeed Moaveni, *Finite Element Analysis: Theory and Application with ANSYS*, (Pearson)
6. Esam M. Alawadhi, *Topology Optimization in Engineering Design with ANSYS* (Elsevier)

Reference Books :

1. Zhi-Hua Zhong, *Finite Element Procedures for Structural Analysis with ANSYS*, (Springer)
2. John Matsson , *An Introduction to ANSYS Fluent 2023*, (SDC Publications)
3. Xin-She Yang, *Introduction to Computational Heat Transfer with MATLAB and ANSYS*, (Elsevier)
4. Karthik Selvam, *Introduction to ANSYS Workbench 2023*, (Springer)
5. Khalid Saeed & M. M. Rashid**,** *Heat Transfer and Thermal Stress Analysis in ANSYS*, (Springer)
6. Andrew Buchanan, *Fatigue and Fracture Mechanics in ANSYS Workbench*, (CRC Press)

Other Resources :

1. **Basics of Finite Element Analysis – I,** Prof. S. K. Bhattacharyya, IIT Kanpur
   Link: https://archive.nptel.ac.in/courses/112/104/112104193/
2. **Finite Element Method,** Prof. Biswanath Banerjee and Prof. Amit Shaw, IIT Kharagpur
   Link: https://onlinecourses.nptel.ac.in/noc22_me43/preview
3. **Finite Element Analysis,** Prof. A. K. Dasgupta, IIT Kharagpur
   Link: https://archive.nptel.ac.in/courses/105/105/105105041/
4. **Finite Element Method,** Prof. S. K. Bhattacharyya, IIT Kanpur
   Link: https://archive.nptel.ac.in/courses/112/105/112105308/
5. **Basics of Finite Element Analysis – II,** Prof. S. K. Bhattacharyya, IIT Kanpur
   Link: https://archive.nptel.ac.in/courses/112/104/112104205/

IN-SEMESTER ASSESSMENT (50 MARKS)

1. Continuous Assessment (20 Marks)

Suggested breakup of distribution

One MCQ test as per GATE exam pattern/ level	:	05 Marks
Class Test	:	05 Marks
Open book test	:	05 Marks
Regularity and active participation	:	05 Marks

2. Mid Semester Exam (30 Marks)

Mid semester examination will be based on 40% to 50% syllabus.

END SEMESTER EXAMINATION (50 MARKS)

End Semester Examination will be based on syllabus coverage up to the Mid Semester Examination carrying 20% to 30% weightage and the syllabus covered from MSE to ESE carrying 70% to 80% weightage.

Course Type	Course Code	Course Name	Credits
PEC	MEPEC5012	COMPUTER AIDED ENGINEERING	03

Examination Scheme					
Distribution of Marks			Exam Duration (Hrs.)		Total Marks
In-semester Assessment		End Semester Examination (ESE)			
Continuous Assessment	Mid-Semester Exam (MSE)		MSE	ESE	
20	30	50	1.5	2	100

Pre-requisite:

1. BSC101: Engineering Mathematics-I
2. BSC102: Engineering Physics-I
3. BSC204: Engineering Mathematics-II
4. BSC205: Engineering Physics-II
5. MEPCC301: Engineering Mathematics-III
6. MEPCC302: Mechanics of Solids
7. MEPCC304: Thermodynamics
8. MEPCC407: Thermal Engineering
9. MEPCC510: Fluid Mechanics and Machinery

Program Outcomes addressed:

1. PO1: Engineering Knowledge
2. PO2: Problem Analysis
3. PO5: Engineering Tool Usage
4. PO6: The Engineer and The World
5. PO8: Individual and Collaborative Team work
6. PO9: Communication
7. PO11: Life-Long Learning

Course Objectives:

1. Introduce students to the fundamentals of CAE and FEA for structural, thermal, CFD, and electromagnetic analysis.
2. Guide students in creating 1D, 2D, and 3D meshes and selecting appropriate elements for accuracy.
3. Train students to assess mesh quality and apply adaptive meshing for better simulations.
4. Familiarize students to the direct and iterative solvers, convergence criteria, and HPC techniques for efficient analysis.

5. Enhance Post-Processing Interpretation through the analysis of stress, strain, deformation, and fatigue life results in structural simulations.

6. Familiarize students to the visualization of velocity, pressure, turbulence, and force analysis in fluid and thermal simulations.

Module	Details	Hrs.
	Course Introduction Computer-Aided Engineering (CAE) is a critical aspect of modern engineering design and analysis. It integrates Finite Element Analysis (FEA) and Computational Fluid Dynamics (CFD) to evaluate structural, thermal, and fluid behavior in engineering applications. This course covers fundamental and advanced topics, including meshing techniques, solver settings, and post-processing methodologies. Students will gain hands-on experience with industry-standard CAE tools, enhancing their ability to solve complex engineering problems efficiently.	**01**
01.	**Introduction to CAE, Types of Elements and Mesh Generation**	**6-8**
	Learning Objective: *To get familiar to the basics of CAE, different types of analysis, and apply mesh quality metrics and adaptive meshing techniques.*	
	Contents: ***Introduction to Computer-Aided Engineering (CAE)***, Overview of different types of analysis like Structural Analysis (e.g., stress, strain, fatigue), Thermal Analysis (e.g., heat transfer, conduction), Fluid Dynamics (CFD) (e.g., airflow, turbulence) ***Geometry:*** 1D, 2D & 3D elements**,** Geometry creation/import & simplification ***Material properties:*** Modulus of Elasticity, Modulus of Rigidity, Poisson's Ratio ***Meshing:*** Element types, mesh quality, and convergence ***Mesh Quality Metrics:*** Aspect Ratio, Jacobian Ratio, Skewness, warping, Adaptive Meshing ***Use of Symmetry***, Planar Symmetry, Axial Symmetry, Cyclic Symmetry	
	Self-Learning Topics: *Advanced Mesh Quality Improvement Techniques*	
	Learning Outcomes: *A learner will be able to* *LO 1.1: Apply the fundamental principles of Computer-Aided Engineering (CAE) to evaluate their application in engineering design. (PI 1.4.1)* *LO 1.2: Compare the role of CAE in structural, thermal, and fluid dynamics simulations. (PI 2.2.4)* *LO 1.3: Apply different methods of geometry creation, import, and simplification in CAE for effectiveness and efficiency. (PI 1.3.1)* *LO 1.4: Apply knowledge of material properties to improve the accuracy of simulation results. (PI 1.2.1)*	

	LO 1.5: Identify the limitations of meshing in the accuracy and efficiency of numerical simulations. (PI 2.4.3) *LO 1.6: Apply the concepts of planar, axial, and cyclic symmetry in CAE modeling, and justify their effectiveness in reducing computational complexity. (PI 2.4.1)*	
02.	**Structural Analysis (Static and Linear)**	**7-9**
	Learning Objective/s: *To select element types, mesh refinement methods, and solvers to ensure convergence and optimize computational performance in FEA.*	
	Contents: ***Introduction*** Basics of static and linear analysis, Theory of elasticity and stress-strain relationships ***Types of elements:*** Solid Elements, Shell Elements, Beam Elements, Tetrahedral Elements *(Different types of elements and element selection to be covered from FEA perspective.)* ***Boundary Conditions:*** Forces, Pressures, Fixed Support, Displacement Support, Frictionless Support, Cylindrical Support, Compression Only Support ***Solver Selection:*** Direct Solver, Iterative Solver *(Background theoretical knowledge related to types of solver to be discussed from FEA perspective)* ***Solver Settings:*** Damping, Large Deflection, Pivot Checking, Inertia Relief *(Basic background of solver settings to be discussed from FEA perspective)* ***Post-Processing***: Stress Contours, Deformation Plots, Safety Factors	
	Self-Learning Topics: --	
	Learning Outcomes: *A learner will be able to* *LO 2.1: Apply the fundamental principles of static and linear analysis in structures using the theory of elasticity. (PI 1.1.2)* *LO 2.2: Identify various boundary conditions and load types in accurately simulating real-world engineering constraints. (PI 2.1.3)* *LO 2.3: Distinguish the element type (solid, shell, beam, and tetrahedral elements) for the structure, justifying selection based on geometry and loading in FEA models. (PI 2.2.4)* *LO 2.4: Articulate the use of direct and iterative solvers, along with solver settings such as damping, large deflection, pivot checking, and inertia relief. (PI 2.1.1)* *LO 2.5: Validate common post-processing outputs like stress contours, deformation plots, and safety factors. (PI 2.4.2)* *LO 2.6: A Task-Based Group Activity Before MSE (Part I) (PI 1.3.1, PI 2.1.2, PI 2.2.4, PI 2.3.1, PI 5.2.2, PI 6.4.2, PI 8.1.2, PI 9.1.2, PI 11.3.1)*	

	Each group (max 4 students) will analyze the stress distribution, deformation, and factor of safety of a structure subjected to different loading conditions using a commercial Finite Element Analysis (FEA) software package. *Following aspects are to be addressed:* *A. Design and Model Creation:* • *Create a 3D CAD model of the structure with assigned material properties (e.g., steel, aluminum).* • *Import the model into the commercial software package for analysis.* *B. Meshing and Preprocessing:* • *Perform mesh refinement and evaluate mesh quality metrics like aspect ratio and skewness.* • *Apply appropriate boundary conditions (fixed support at one end).* *C. Load Application:* • *Apply different types of loads (point loads, distributed loads, moment loads) at various locations.* • *Vary magnitudes of force to observe the beam's response under different conditions.* *D. Analysis and Simulation:* • *Conduct static structural analysis to determine stress, strain, and deformation distribution.* • *Compare results across different load cases and mesh densities.* *E. Results Interpretation:* • *Identify failure points and factor of safety.* • *Optimize the beam's design by modifying cross-sectional dimensions or material properties.* • *Validate the FEA results with theoretical calculations.*	
03.	**Dynamic and Modal Analysis**	**6-8**
	Learning Objective: *Apply post processing tools to analyze displacement, stress, and strain contours, evaluate design reliability, assess convergence, and visualize modal analysis to identify resonance risks and estimate fatigue life.*	
	Contents:	
	Introduction Significance and basics of Modal, Harmonic and Transient Analysis, Natural Frequencies and Mode Shapes ***Modal Analysis*** ***Element Types:*** Solid, Shell, Beam ***Boundary Conditions:*** Fixed Support, Displacement Support ***Solver Selection***: Subspace Iteration Method, Block Lanczos Method ***Solver Settings:*** Number of Modes, Frequency Range ***Post-Processing:*** Mode Shapes, Natural Frequencies ***Harmonic and Transient Analysis*** ***Element Types:*** Solid, Shell, Beam ***Boundary Conditions:*** Harmonic Loads, Transient Loads ***Solver:*** Full Method, Reduced Method (CMS), Mode Superposition ***Solver Settings:*** Damping, Time Step, Load Frequency	

	Post-Processing: Frequency Response Plots, Time History Plots, Stress and Deformation Contours	
	Self-Learning Topics --	
	Learning Outcomes: *A learner will be able to* *LO 3.1: Apply the significance and fundamental concepts of Modal, Harmonic, and Transient analysis, including natural frequencies and mode shapes in dynamic systems. (PI 1.4.1)* *LO 3.2: Differentiate between solid, shell, and beam elements, and justify their use in dynamic analyses. (PI 2.2.4)* *LO 3.3: Identify appropriate boundary and loading conditions in modal, harmonic, and transient analyses, and recognize key system variables and parameters that influence dynamic behavior. (PI 2.1.2)* *LO 3.4: Validate outputs like mode shapes, frequency response, and time history plots, and evaluate their importance. (PI 2.4.2)* *LO 3.5: A Task-Based Group Activity Before MSE (Part II) (PI 1.3.1, PI 2.1.2, PI 2.2.4, PI 2.3.1, PI 5.2.2, PI 6.4.2, PI 8.1.2, PI 9.1.2, PI 11.3.1)* *Each group (max 4 students) will perform modal, harmonic, and transient analysis on a structure using a commercial Finite Element Analysis (FEA) software package, investigating its natural frequencies, mode shapes, harmonic response, and transient behavior.* *Following aspects are to be addressed:* *A. Design and Model Creation:* • *Create a 3D CAD model of the structure with assigned material properties (e.g., steel, aluminum).* • *Import the model into the commercial software package for analysis.* *B. Modal Analysis:* • *Apply fixed boundary conditions at appropriate point.* • *Solve for natural frequencies and mode shapes using the Eigenvalue solver with multiple modes.* • *Interpret mode shapes to understand vibration characteristics.* *C. Harmonic Analysis:* • *Apply harmonic loads with varying frequencies.* • *Use a harmonic response solver to examine resonance effects and frequency response plots.* • *Study the effects of damping.* *D. Transient Analysis:* • *Introduce transient loads to observe time-dependent deformation.* • *Use a transient dynamic solver to analyze stress variations over time.* *E. Results Interpretation* • *Generate time history plots to visualize dynamic behavior.*	
04.	**Introduction to Computational Fluid Dynamics**	**6-8**
	Learning Objectives: *To comprehend the basics of CFD, including flow equations, numerical methods, element types, mesh generation, and boundary conditions using simulation tools.*	
	Contents: ***Introduction*** History, significance and applications of CFD, Governing Equations of Fluid Flow: Navier-Stokes Equations, Numerical Methods in CFD (Finite Volume Method)	

	Computational tools Introduction to CAD modelling, Types of Elements (1D, 2D, 3D and surface), Selection of elements according to specific application ***Material:*** Properties of materials, selection of materials ***Grid Generation and Mesh Types*** Structured, Unstructured, Hybrid, Mesh Quality Metrics and Refinement Techniques ***Boundary Conditions and Initial Conditions*** Velocity Inlet, Pressure Inlet, Pressure Outlet, Outflow, Wall, Symmetry /Axis, Periodic, Standard Initialization, Hybrid Initialization, Patch Initialization	
	Self-Learning Topics: *CFD Mesh Generation and Refinement Techniques*	
	Learning Outcomes: *A learner will be able to* *LO 4.1: Apply the significance and applications of Computational Fluid Dynamics (CFD). (PI 1.4.1)* *LO 4.2: Apply governing fluid flow equations and numerical method like the Finite Volume Method to solve practical engineering problems using Computational Fluid Dynamics (CFD). (PI 1.1.2)* *LO 4.3: Identify relevant material properties and selection criteria within a CFD tool to define system parameters influencing fluid-structure interaction and thermal behaviour. (PI 2.1.2)* *LO 4.3: Classify element types (1D, 2D, 3D, surface) and justify element selection based on geometry and application. (PI 2.2.4)* *LO 4.4: Extract key differences among mesh types (structured, unstructured, hybrid) and interpret mesh quality metrics to draw conclusions consistent with analysis objectives and limitations. (PI 2.4.4).* *LO 4.5: Apply appropriate boundary and initial conditions in CFD simulations, including various inlet, outlet, wall, and initialization types, to ensure accurate solution setup. (PI 2.4.1)*	
05.	**Fluid Analysis** ***Learning Objective/s:*** *To apply pressure-based and density-based solvers, select turbulence models, and set convergence criteria for flow simulations.*	**6-8**
	Contents:	
	Pressure-Based Solver for Incompressible Flows, Density-Based Solver for High-Speed Compressible Flows, Time Stepping (Steady vs. Transient), Turbulence Modelling Settings, RANS Models, k-ε, k-ω (Standard, SST), LES (Large Eddy Simulation) & DES (Detached Eddy Simulation), Convergence Criteria & Residual Controls, Residual Convergence Criteria.	

Post Processing: Visualization Tools: Contours, Streamlines, and Vectors, ISO-Surface and Cut Plane Visualization, Quantitative Analysis: Force, Drag, Lift, Data Export.

Self-Learning Topics:

Pressure Velocity Coupled Scheme

Learning Outcomes :

A learner will be able to

LO 5.1: Distinguish between pressure-based and density-based solvers and evaluate their applications in incompressible and compressible flow simulations. (PI 2.2.4)

LO 5.2: Combine fluid dynamics principles and engineering concepts to formulate suitable steady or transient time-stepping models and select turbulence approaches like RANS, LES, or DES based on applicability and accuracy. (PI 2.3.1)

LO 5.3: Identify convergence criteria and residual control parameters within engineering simulations to solve problems related to simulation accuracy. (PI 2.1.2)

LO 5.4: Validate CFD results through skilful use of visualization tools like contours, streamlines, and cut planes, and interpretation of quantitative data such as force, drag, and lift. (PI 2.4.4)

LO 5.5: A Task-Based Group Activity After MSE (Part III) (PI 1.3.1, PI 1.4.1, PI 2.1.2, PI 2.2.4, PI 2.3.1, PI 5.2.2, PI 6.4.2, PI 8.1.2, PI 9.1.2, PI 11.3.1)

Each group (max 4 students) will simulate and analyze fluid flow behavior over a 2D or 3D geometry using appropriate solvers and turbulence models. Students will apply pressure-based and/or density-based solvers, select steady or transient analysis, and evaluate aerodynamic quantities like drag and lift using post-processing tools.

Following aspects are to be addressed:

A. Problem Definition & Geometry Selection:
- *Choose a 2D airfoil (e.g., NACA 0012) or a 3D bluff body (e.g., cylinder, sphere).*
- *Define the objective: e.g., analyze drag at various flow speeds or investigate vortex shedding.*

B. Pre-Processing:
- *Create/import geometry in appropriate software module.*
- *Generate mesh (structured/unstructured) and perform mesh refinement study.*
- *Identify suitable boundary and initial conditions.*

C. Solver Setup:
- *Select pressure-based solver for subsonic flows or density-based for high-speed compressible flow.*
- *Use steady or transient time-stepping as appropriate.*
- *Choose and justify a turbulence model:*
- *(e.g., k-ε for general flow, k-ω SST for wall-bounded flows, LES/DES for unsteady separations).*

D. Solver Setup:
- *Select pressure-based solver for subsonic flows or density-based for high-speed compressible flow.*
- *Use steady or transient time-stepping as appropriate.*
- *Choose and justify a turbulence model:*
- *(e.g., k-ε for general flow, k-ω SST for wall-bounded flows, LES/DES for unsteady separations).*

E. Post-Processing:
- *Use contours, streamlines, vectors, ISO-surfaces, and cut planes for flow visualization.*
- *Extract quantitative data: lift, drag, pressure forces.*

	• *Export data for plotting and comparison.* *F. Post-Processing:* • *Use contours, streamlines, vectors, ISO-surfaces, and cut planes for flow visualization.* • *Extract quantitative data: lift, drag, pressure forces.* • *Export data for plotting and comparison.*	
06.	**Thermal Analysis**	**6-8**
	Learning Objective/s: *Demonstrate the ability to set up, solve, and analyze heat transfer and thermo-mechanical problems using appropriate numerical methods, solver settings, boundary conditions, and post-processing techniques*	
	Contents: ***Different modes of heat transfer:*** Conduction, Convection, and Radiation ***Steady-State and Transient Thermal Analysis:*** ***Elements:*** Solid, Shell, Line ***Material Properties:*** Thermal Conductivity, Specific Heat Capacity, Density, Emissivity ***Boundary Conditions:*** Convection, Radiation, Temperature, Heat Flux, Adiabatic ***Solver Selection:*** Steady-State, Transient Thermal ***Solver Settings:*** Initial Conditions, Time Step (for Transient), Convergence Criteria ***Post-Processing:*** Temperature Contours, Heat Flux Vectors, Thermal Gradients ***Thermo-Mechanical Coupling: Thermal Stresses and Expansion*** ***Elements:*** Solid, Shell ***Material Properties:*** Modulus of Elasticity, Modulus of Rigidity, Poisson's Ratio, Thermal Conductivity, Specific Heat Capacity, Density, Thermal Expansion Coefficient, Emissivity ***Boundary Conditions:*** Thermal Loads, Mechanical Loads ***Solver:*** Thermo-Mechanical ***Settings***: Temperature Dependent, Coupled Field Analysis, Convergence Criteria ***Post-Processing:*** Thermal Stress Contours, Displacement Plots, Thermal Strain	
	Self-Learning Topics: --	
	Learning Outcomes: *A learner will be able to* *LO 6.1: Apply the fundamental modes of heat transfer-conduction, convection, and radiation-and evaluate their relevance in engineering applications. (PI 1.4.1)* *LO 6.2: Identify key material properties and parameters that influence thermal and thermos-mechanical behavior in engineering applications. (PI 2.1.2)*	

	LO 6.3: Differentiate between steady-state and transient thermal analyses, and identify appropriate boundary conditions, solver types, and settings for various thermal problems. (PI 2.3.1) *LO 6.4: Validate post-processing results such as temperature contours, heat flux vectors, and thermal gradients in thermal simulations. (PI 2.4.2)* *LO 6.5: Identify the mathematical, engineering, and relevant knowledge involved in thermo-mechanical coupling, including thermal loads and expansion, necessary for modeling thermal stress and strain using coupled field simulations. (PI 2.1.3)* *LO 6.6: A Task-Based Group Activity After MSE (Part IV) (PI 1.3.1, PI 2.1.2, PI 2.2.4, PI 2.3.1, PI 5.2.2, PI 6.4.2, PI 8.1.2, PI 9.1.2, PI 11.3.1)* *Each group (max 4 students) will simulate heat transfer and thermo-mechanical behavior of an engineering component under thermal loads using steady-state and transient analysis. Students will identify suitable boundary conditions, solver settings, and evaluate post-processing results to predict performance, deformation, and potential failure.* *Following aspects are to be addressed:* *A. Component Selection and Problem Definition:* • *Choose a real-world component (e.g., electronic chip, brake disc, exhaust manifold, turbine blade).* • *Define the operating environment, heat sources, and mechanical constraints.* *B. Pre-Processing:* • *Model or import geometry in appropriate software module.* • *Choose appropriate element type (solid or shell) and generate mesh.* • *Assign material properties, including temperature-dependent behavior.* *C. Thermal Analysis (Phase 1):* • *Apply steady-state and transient thermal boundary conditions: convection, radiation, heat flux, etc.* • *Select the correct thermal solver and configure time steps and convergence criteria.* • *Simulate and post-process: generate temperature contours, heat flux vectors, and thermal gradients.* *D. Thermo-Mechanical Analysis (Phase 2):* • *Use temperature results as input for coupled field analysis.* • *Apply mechanical boundary conditions (fixed supports, pressure loads).* • *Define thermal expansion coefficients and temperature-dependent material properties.* • *Run the simulation and post-process: obtain thermal stress contours, displacement plots, and thermal strain.* *E. Report and Presentation:* • *Document the problem, methodology, simulation settings, results, and conclusions in a formal report.* • *Create a presentation summarizing key results, visualizations, and insights.*	
	Course Conclusion	**01**
	Total	**45**

Performance Indicators:

P.I. No.	P.I. Statement
1.1.2	Apply advanced mathematical techniques to model and solve mechanical engineering problems.
1.2.1	Apply laws of natural science to an engineering problem.

1.3.1 Apply fundamental engineering concepts to solve engineering problems.

1.4.1 Apply Mechanical engineering concepts to solve engineering problems.

2.1.1 Articulate problem statements and identify objectives

2.1.2 Identify engineering systems, variables, and parameters to solve the problems.

2.1.3 Identify the mathematical, engineering and other relevant knowledge that applies to a given problem

2.2.4 Compare and contrast alternative solution processes to select the best process.

2.3.1 Combine scientific principles and engineering concepts to formulate model/s (mathematical or otherwise) of a system or process that is appropriate in terms of applicability and required accuracy.

2.4.1 Apply engineering mathematics and computations to solve mathematical models.

2.4.2 Produce and validate results through skilful use of contemporary engineering tools and models.

2.4.3 Identify sources of error in the solution process, and limitations of the solution.

2.4.4 Extract desired understanding and conclusions consistent with objectives and limitations of the analysis.

5.2.2 Demonstrate proficiency in using discipline-specific tools.

6.4.2 Apply principles of preventive engineering and sustainable development to an engineering activity or product relevant to the discipline.

8.1.2 Implement the norms of practice (e.g., rules, roles, charters, agendas, etc.) of effective team work, to accomplish a goal.

9.1.2 Produce clear, well-constructed, and well-supported written engineering documents.

11.3.1 Source and comprehend technical literature and other credible sources of information.

Course Outcomes: A learner will be able to -

1. Analyse the fundamental principles and applications of Computer-Aided Engineering (CAE) tools across structural, thermal, and fluid domains. *(LO 1.1, LO 1.2, LO 1.4, LO 4.1, LO 6.1)*

2. Apply appropriate modelling techniques, material properties, and symmetry concepts to improve simulation accuracy and computational efficiency in CAE. *(LO 1.3, LO 1.5, LO 1.6, LO 4.3, LO 6.2)*

3. Evaluate and implement boundary conditions, solver settings, and element types in structural, dynamic, thermal, and CFD analyses. *(LO 2.2, LO 2.3, LO 2.4, LO 3.2, LO 3.3, LO 4.5, LO 5.1, LO 5.2, LO 6.3)*

4. Analyse solver methodologies such as static, dynamic, and thermal solvers, and assess time-stepping, turbulence modelling, and convergence strategies for accurate simulations. *(LO 2.1, LO 3.1, LO 5.2, LO 5.3, LO 6.3, LO 6.5)*

5. Interpret and analyse post-processing results from structural, CFD, and thermal simulations to support engineering decisions. *(LO 2.5, LO 3.4, LO 5.4, LO 6.4)*

6. Collaborate in task-based activities to solve multidisciplinary engineering problems using CAE tools, demonstrating teamwork, communication, and technical skills. *(LO 2.6, LO 3.5, LO 5.5, LO 6.6)*

CO-PO Mapping Table with Correlation Level

CO ID	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MEPE5012.1	3	3	--	--	--	--	--	--	--	--	--
MEPE5012.2	3	3	--	--	2	2	--	2	2	--	2
MEPE5012.3	3	3	--	--	2	2	--	2	2	--	2
MEPE5012.4	3	3	--	--	--	--	--	--	--	--	--
MEPE5012.5	3	3	--	--	2	2	--	2	2	--	2
MEPE5012.6	3	3	--	--	2	2	--	2	2	--	2
Average	**3**	**3**	--	--	**2**	**2**	--	**2**	**2**	--	**2**

NOTE: CO can be mapped to PO at level 3 if at least two PIs are associated with that CO; otherwise, it can be mapped at level 2.

Text Books :

1. S. S. Rao, The Finite Element Method in Engineering, 6th Edition, Butterworth-Heinemann, 2018.
2. T. J. R. Hughes, The Finite Element Method: Linear Static and Dynamic Finite Element Analysis, Dover Publications, 2000.
3. R. K. Mittal, Computational Fluid Dynamics, 1st Edition, Cengage Learning India, 2015.
4. M. D. Raisinghani, Computational Fluid Dynamics, 1st Edition, Narosa Publishing House, 2007.
5. John D. Anderson Jr., Computational Fluid Dynamics: The Basics with Applications, 1st Edition, McGraw-Hill, 1995.
6. Rainald Löhner, Applied Computational Fluid Dynamics Techniques, 1st Edition, Springer, 2008.
7. Olek C. Zienkiewicz, Robert L. Taylor, Jianzhong Zhu, The Finite Element Method: Its Basis and Fundamentals, 7th Edition, Butterworth-Heinemann, 2013.
8. J. N. Reddy, An Introduction to the Finite Element Method, 4th Edition, McGraw-Hill Education, 2019.

Reference Books :

1. O. C. Zienkiewicz, R. L. Taylor, The Finite Element Method: Its Basis and Fundamentals, 7th Edition, Elsevier, 2013.
2. Klaus-Jürgen Bathe, Finite Element Procedures, 2nd Edition, Prentice Hall, 2014.
3. David Hutton, Fundamentals of Finite Element Analysis, 1st Edition, McGraw-Hill, 2004.

4. H. K. Versteeg, W. Malalasekera, An Introduction to Computational Fluid Dynamics: The Finite Volume Method, 2nd Edition, Pearson, 2007.
5. S. S. Rao, The Finite Element Method in Engineering, 6th Edition, Butterworth-Heinemann, 2018.
6. Joel H. Ferziger, Milovan Perić, Robert L. Street, Computational Methods for Fluid Dynamics, 4th Edition, Springer, 2020.
7. Daryl L. Logan, A First Course in the Finite Element Method, 6th Edition, Cengage Learning, 2016.

Other Resources :

1. NPTEL Course: Finite Element Analysis
   Web link: https://nptel.ac.in/courses/112/101/112101115/
2. NPTEL Course: Introduction to Computational Fluid Dynamics
   Web link: https://nptel.ac.in/courses/101/104/101104013/
3. NPTEL Course: Computer Methods in Mechanics
   Web link: https://nptel.ac.in/courses/112/106/112106317/
4. NPTEL Course: Computational Fluid Dynamics
   Web link: https://nptel.ac.in/courses/112/106/112106142/
5. NPTEL Course: Numerical Methods and Computational Techniques
   Web link: https://nptel.ac.in/courses/111/105/111105071/
6. NPTEL Course: Structural Analysis
   Web link: https://nptel.ac.in/courses/105/105/105105071/
7. NPTEL Course: Product Design & Manufacturing using CAE
   Web link: https://nptel.ac.in/courses/112/103/112103174/
8. NPTEL Course: Finite Element Analysis
   Web link: https://nptel.ac.in/courses/112/101/112101022/

IN-SEMESTER ASSESSMENT (50 MARKS)

1. Continuous Assessment – Theory (20 Marks)

Suggested breakup of distribution

One MCQ test as per GATE exam pattern/ level	:	05 Marks
A task based group activity, before MSE. (Part I)	:	05 Marks
A task based group activity, after MSE. (Part II)	:	05 Marks
Regularity and active participation	:	05 Marks

2. Mid Semester Exam (30 Marks)

Mid semester examination will be based on 40% to 50% syllabus.

END SEMESTER EXAMINATION (50 MARKS)

End Semester Examination will be based on syllabus coverage up to the Mid Semester Examination (MSE) carrying 20%-30% weightage, and the syllabus covered from MSE to ESE carrying 70%-80% weightage.

Course Type	Course Code	Course Name	Credits
PEC	MEPEC5013	COMPUTATIONAL FLUID DYNAMICS	03

Examination Scheme					
Distribution of Marks			Exam Duration (Hrs.)		Total Marks
In-semester Assessment		End Semester Examination (ESE)			
Continuous Assessment	Mid-Semester Exam (MSE)		MSE	ESE	
20	30	50	1.5	2	100

Pre-requisite:

1. BSC102- Engineering Physics-I
2. BSC205- Engineering Physics-II
3. MEPCC304-Thermodynamics
4. MEPCC407 – Thermal Engineering
5. MEPCC510 – Fluid Mechanics and Machinery

Program Outcomes addressed:

1. PO1: Engineering Knowledge
2. PO2: Problem Analysis
3. PO3: Design/Development of Solutions
5. PO5: Engineering Tool Usage
6. PO6: The Engineer and the World
7. PO11: Life-Long Learning

Course Objectives:

1. To acquaint with the fundamentals and applications of Computational Fluid Dynamics (CFD) in engineering.
2. To inculcate the significance of governing equations like the Navier-Stokes equations and numerical methods (FVM, FDM, FEM).
3. To impart skills in pre-processing, solver setup, and post-processing within the CFD workflow.
4. To inculcate the usage of CFD tools like ANSYS Fluent/CFX for practical and research-oriented applications.

Module	Details	Hrs.
	Course Introduction This course covers the basics of Computational Fluid Dynamics (CFD), including Navier-Stokes equations and numerical methods like Finite Volume and Finite Element. Students will learn grid generation, mesh quality, and element selection using tools like Design Modeller. Key topics include turbulence modeling, multiphase flow, and combustion. By the end, students will be able to simulate and analyze fluid dynamics in engineering applications.	**01**
01.	**Introduction to Computational Fluid Dynamics**	**5-7**
	Contents: Basics of CFD and its Applications, Governing Equations of Fluid Flow: Navier-Stokes Equations, Numerical Methods in CFD (Finite Volume,	

	Finite Difference, Finite Element Methods), Role of Pre-processing, Solvers, and Post-processing in CFD Workflow	
	Self-Learning Topics: *Different tools/software available for CFD simulations.*	
	Learning Outcomes: *A learner will be able to* *LO 1.1: Apply numerical methods to solve fluid dynamics problems related to various engineering field. (P.I.-1.1.1)* *LO 1.2: Apply advanced mathematical techniques to model and solve mechanical engineering problems. (P.I.-1.1.2)* *LO 1.3: Identify the various numerical model and its relevance with respect to engineering problem. (P.I.-2.1.3)* *LO 1.4: Compare various numerical model based on real life application. (P.I.-2.2.4)*	
02.	**Essentials of CFD Tools** ***Learning Objective:*** *To comprehend the features and workflow, and Design Modeller/SpaceClaim.*	**5-7**
	Contents: Introduction to Computational tools and Design Modeller/Space Claim, Types of Elements (1D, 2D, 3D and surface), Selection of elements according to specific application, Grid Generation and Mesh Types (Structured, Unstructured, Hybrid), Mesh Quality Metrics and Refinement Techniques, Introduction to Boundary Conditions and Initial Conditions.	
	Self-Learning Topics: *Comparative simulation analysis between different software.*	
	Learning Outcomes: *A learner will be able to* *LO 2.1: Apply the concepts of boundary and initial conditions in numerical simulations. (1.2.1)* *LO 2.2: Identify and differentiate between various types of elements (1D, 2D, 3D, and surface) and their applications in simulations. (P.I.-2.1.3)* *LO 2.3: Analyze grid generation, mesh quality assessment, and refinement techniques. (5.2.2)* *LO 2.4: Analyze the features of ANSYS Fluent, CFX, and Design Modeller/Space Claim and their relevance in engineering design. (P.I.-5.2.2)*	
03.	**Solver Setup and Solution Techniques** ***Learning Objective:*** *To inculcate the process of setting up solvers for computational simulations, including the selection of appropriate physical and turbulence models.*	**5-7**
	Contents: Selection of Physical Models (Single-phase, Multiphase, Heat Transfer, etc.), Turbulence Models (k-epsilon, k-omega, SST) and Their Applications, Pressure and Velocity Coupling Schemes (SIMPLE, PISO), Convergence Criteria and Residual Monitoring.	

	Self-Learning Topics: *solver efficiency across different CFD platforms like ANSYS Fluent, OpenFOAM, and COMSOL*	
	Learning Outcomes: *A learner will be able to* *LO 3.1: Identify turbulence models (k-epsilon, k-omega, SST) and their application in solving practical fluid dynamics problems. (P.I.-2.1.3)* *LO 3.2: Identify and select appropriate physical models for various types of fluid flow simulations. (P.I.-2.2.2)* *LO 3.3: Identify convergence criteria and residuals to ensure the accuracy and reliability of simulation results. (P.I.-3.2.3)* *LO 3.4: Apply pressure and velocity coupling schemes effectively to achieve stable and accurate solutions. (P.I.-3.3.1)*	
04.	**Post-Processing Techniques** ***Learning Objectives:*** *To acquaint with visualization tools in analyzing simulation results, including contours, streamlines, and vectors.*	**5-7**
	Contents: Visualization Tools: Contours, Streamlines, and Vectors, ISO-Surface and Cut Plane Visualization, Quantitative Analysis: Force, Drag, Lift, and Heat Transfer Coefficients, Data Export and Comparison with Experimental Results.	
	Self-Learning Topics: ***Case studies demonstrating the use of visualization tools in*** *aerospace, automotive, and biomedical engineering*	
	Learning Outcomes: *A learner will be able to* *LO 4.1: Identify visualization tools like contours, streamlines, and vectors to interpret fluid flow behavior effectively. (P.I.-2.2.2)* *LO 4.2: Identify various techniques for ISO-surface and cut-plane visualization to study complex fluid flows. (P.I.-2.2.3)* *LO 4.3: Visualize tools like contours and streamlines help identify inefficiencies and potential risks in fluid flow and thermal systems, aiding in sustainable design improvements. (P.I.-6.3.1)* *LO 4.4: Understand quantitative analysis results, including force, drag, lift, and heat transfer coefficients, to determine the sustainability and practicality of engineering designs. (P.I.-6.3.2)*	
05.	**Multiphase and Transient Analysis in ANSYS Fluent** ***Learning Objective/s:*** *To inculcate the fundamental approaches to simulating multiphase flows using Volume of Fluid (VOF) and Eulerian models.*	**4-6**
	Contents: Multiphase Flow Simulation: Volume of Fluid (VOF) and Eulerian Models, Transient Analysis for Unsteady Flow Problems, Free Surface Flow and Phase Change Simulations, Applications: Bubble Dynamics, Sloshing, and Phase Change	
	Self-Learning Topics: *Case study on multiphase and transient flow.*	

	Learning Outcomes : *A learner will be able to* *LO 5.1: Apply multiphase and transient simulation techniques to solve practical engineering problems. (P.I.-1.2.1)* *LO 5.2: Identify free surface flows and phase change phenomena for applications such as sloshing and bubble dynamics. (P.I.-2.2.2)* *LO 5.3: Compare Volume of Fluid (VOF) and Eulerian models to simulate multiphase flows in engineering applications. (P.I.-2.2.4)*	
06.	**Combustion and Optimization in Computational Tool** ***Learning Objective/s:*** *To impart the principles of combustion modelling, including premixed, non-premixed, and partially premixed models.*	**4-6**
	Contents: Combustion Modelling: Premixed, Non-Premixed, and Partially Premixed Models, Chemical Reaction Mechanisms and Species Transport, Parametric Studies and Optimization using Design-Xplorer in ANSYS, Automation of CFD Workflows with User-Defined Functions (UDFs)	
	Self-Learning Topics: *Combustion and optimization in CFD using different solver.*	
	Learning Outcomes: *A learner will be able to* *LO 6.1: Identify the effectiveness and applications of various numerical methods for solving fluid motion equations. (P.I.-3.2.3)* *LO 6.2: Apply grid generation techniques, such as algebraic and elliptic methods, to solve fluid dynamics problems. (P.I.-3.3.1)* *LO 6.3: Understanding different combustion modeling approaches (premixed, non-premixed, partially premixed) ensures engineers stay updated on advanced simulation techniques, reinforcing the need for continuous professional development. (P.I.-11.1.1)* *LO 6.4: Identify chemical reaction mechanisms and species transport which allows engineers to recognize gaps in combustion modeling and use credible sources to improve simulation accuracy. (P.I.-11.1.2)*	
	Course Conclusion Students will gain understanding of CFD principles and practical applications. They will be skilled in numerical methods, CFD workflows, and using software tools for simulations. The course covers advanced topics like multiphase flows and combustion modeling. Graduates will be prepared to solve complex fluid flow problems and optimize designs.	**01**
	Total	**45**

Performance Indicators:

P.I. No.	**P.I. Statement**
1.1.1	Apply mathematical techniques such as calculus, linear algebra, and statistics to solve problems.

1.1.2 Apply advanced mathematical techniques to model and solve mechanical engineering problems.

1.2.1 Apply laws of natural science to an engineering problem.

2.1.3 Identify the mathematical, engineering and other relevant knowledge that applies to a given problem

2.2.2 Identify, assemble and evaluate information and resources

2.2.3 Identify existing processes/solution methods for solving the problem, including forming justified approximations and assumptions.

2.2.4 Compare and contrast alternative solution processes to select the best process.

2.4.3 Identify sources of error in the solution process, and limitations of the solution.

3.2.3 Identify suitable criteria for the evaluation of alternate design solutions

3.3.1 Apply formal decision-making tools to select optimal engineering design solutions for further development.

5.2.2 Demonstrate proficiency in using discipline-specific tools.

6.3.1 Identify risks/impacts in the life-cycle of an engineering product or activity

6.3.2 Understand the relationship between the technical, socio-economic and environmental dimensions of sustainability

11.1.1 Describe the rationale for the requirement for continuing professional development

11.1.2 Identify deficiencies or gaps in knowledge and demonstrate an ability to source information to close this gap

Course Outcomes: A learner will be able to -

1. Apply fundamental principles of Computational Fluid Dynamics (CFD) and numerical methods (FVM, FDM, FEM) to solve fluid flow problems. (*LO 1.1, LO 1.2,LO 1.3, LO1.4*)
2. Analyse mesh quality and assess mesh refinement techniques to improve simulation accuracy. (*LO 2.1, LO 2.2,LO 2.3, LO 2.4*)
3. Identify various numerical model and its application in simulation. (*LO 1.3, LO 1.4, LO 3.1, LO 3.2, LO 3.3, LO 3.4*)
4. Analyze CFD simulation results using post-processing techniques such as contour and streamlines to evaluate the thermal performance. (*LO 3.3, LO 3.4, LO 4.1, LO 4.2, LO 4.3, LO 4.4*)
5. Analyze transient multiphase flow problem and combustion modelling. (*LO 5.1, LO 5.2, LO 5.3, LO 6.1, LO 6.2, LO 6.3, LO 6.4*)

CO-PO Mapping Table with Correlation Level

CO ID	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MEPEC5013.1	3	3	--	--	--	--	--	--	--	--	--
MEPEC5013.2	2	2	--	--	2	--	--	--	--	--	--
MEPEC5013.3	--	3	3	--	--	--	--	--	--	--	--
MEPEC5013.4	--	3	3	--	--	3	--	--	--	--	--

MEPEC5013.5	2	3	3	--	--	--	--	--	--	--	3
Average	**2**	**3**	**3**	**--**	**2**	**3**	**--**	**--**	**--**	**--**	**3**

Text Books :

1. Introduction to Computational Fluid Dynamics by H.K. Versteeg and W. Malalasekera.
2. Numerical Heat Transfer and Fluid Flow by S.V. Patankar, Hemisphere Publishing Company.
3. Computational Fluid Dynamics by T.J. Chung, Cambridge University Press 2003
4. Computational fluid flow and heat transfer by K. Murlidhar and T. Sounderrajan, Narosa Publishing Co.
5. An Introduction to Computational Fluid Dynamics by Versteeg, H.K. and Malalasekara, W., , Pearson Education, 2010.

Reference Books :

1. Computational fluid dynamics by J.A. Anderson, McGraw-Hill Publications 1995
2. Computational fluid mechanics and heat transfer by D. A. Anderson, J. C. Tannehill, R.H. Pletcher, Tata McGraw-Hill Publications 2002
3. An Introduction to Computational Fluid Dynamics: The Finite Volume Method by H. Versteeg and W. Malalasekera
4. Computational Fluid Dynamics by T.J. Chung. 2002

Other Resources :

1. NPTEL Managed by IITs and IISC
2. OpenCourseWare (MIT, TUDelft, Yale University, edX, Coursera etc.)
3. Research papers and Discussion forums (researchgate, academia.edu)

IN-SEMESTER ASSESSMENT (50 MARKS)

1. Continuous Assessment - Theory-(20 Marks)

Suggested breakup of distribution

Numerical Assignments (Minimum 20 problems): 5 marks

Class test based on above Numerical assignment: 5 marks

A task based on group activity: 5 marks

Regularity and active participation: 5 marks

2. Mid Semester Exam (30 Marks)

Mid semester examination will be based on 40% to 50% syllabus.

END SEMESTER EXAMINATION (50 MARKS)

End Semester Examination will be based on syllabus coverage up to the Mid Semester Examination (MSE) carrying 20%-30% weightage, and the syllabus covered from MSE to ESE carrying 70%-80% weightage.

Course Type	Course Code	Course Name	Credits
LBC	MELBC506	MECHANICAL VIBRATIONS LABORATORY	01

Examination Scheme		
Continuous Assessment	**End Semester Exam (ESE)**	**Total**
25	25	50

Pre-requisite:

1. MEPCC302: Mechanics of Solids
2. MEPCC406: Theory of Machines

Program Outcomes addressed:

1. PO1: Engineering Knowledge
2. PO2: Problem Analysis
3. PO4: Conduct investigations of complex problems
4. PO5: Engineering tool usage
5. PO8: Individual and collaborative team work
6. PO9: Communication

Course Objectives:

1. To familiarize students with the measurement and analysis of vibrational characteristics in mechanical systems.
2. To impart practical skills in using vibration analysis tools and techniques.
3. To enable students to validate theoretical concepts through experimental work.
4. To familiarize students with the measurement and analysis of vibrational characteristics in mechanical systems.

Module	**Details**	Hrs.
	Course Introduction The Mechanical Vibrations Laboratory is a practical course designed to complement the theoretical concepts of mechanical vibrations. It aims to provide hands-on experience in analyzing and interpreting the vibrational behavior of mechanical systems. Students will perform experiments to measure natural frequencies, damping ratios, and resonance conditions in various systems, including spring-mass setups, beams, and torsional shafts.	
01.	**Free Vibration Analysis** ***Learning Objective:*** *To impart fundamental concepts of free vibrations and analyze the dynamic behavior of mechanical systems for practical engineering applications.*	**08**

	Self-Learning Topics: *Fundamentals and basic concepts of vibrations.*	
	Theme for conducting Experiment: 1. Determination of the radius of gyration using a bi-filar and trifilar system. ***Learning Outcome:*** *A learner will be able to* *LO 1.1: Model and analyze bifilar and trifilar suspension systems to determine the moment of inertia of mechanical components, perform team-based experimentation, and communicate results effectively using technical documentation. (P.I. 2.3.1, 4.3.1, 8.1.2, 9.1.2)*	
	Theme for conducting Experiment: 2. Determination of natural frequency in a longitudinal vibrating system ***Learning Outcome:*** *A learner will be able to* *LO 1.2: Apply Newton's law to mathematically model longitudinal vibrations in single and multiple spring systems, determine equivalent stiffness and natural frequency analytically and experimentally, while working collaboratively to conduct tests, interpret results, and present technical findings through well-structured reports and presentations.(PI 1.1.2, PI 2.3.1, PI 4.1.4, PI 8.1.2, PI 9.1.2)*	
	Theme for conducting Experiment: 3. Determination of natural frequency of undamped torsional vibration of a single and two rotor shaft system. ***Learning Outcome:*** *A learner will be able to* *LO 1.3: Use analytical techniques and experimental procedures to evaluate the natural frequency of undamped torsional vibrations in single and dual-rotor systems, while functioning as a team to document and present results effectively.(PI 1.4.1, PI 2.1.3, PI 4.3.1, PI 8.1.2, PI 9.1.2)*	
02.	**Forced Vibration Analysis** ***Learning Objective:*** *To introduce fundamental concepts of vibration analysis and dynamics to investigate the dynamic behavior of forced vibration systems using appropriate experimental approaches and tools.*	**06**

	Self-Learning Topics: *Fundamentals of forced vibration and computational method*	
	Theme for conducting Experiment: 1. To study the forced vibration of the beam with different boundary conditions. ***Learning Outcome:*** *A learner will be able to* *LO 2.1: Apply Newton's law and vibration theory to model and analyze forced vibration responses of beams under varying boundary conditions, determine damping behavior using analytical and experimental methods, while working collaboratively to interpret data and communicate results through technical documentation and presentations.(PI 1.1.2, PI 2.3.1, PI 4.3.1, PI 8.1.2, PI 9.1.2)*	
	Theme for conducting Experiment: 2. Determination of force transmissibility ratio in a forced vibration system. ***Learning Outcome:*** *A learner will be able to* *LO 2.2: Use appropriate vibration analysis techniques to determine the force transmissibility ratio in a forced vibration system, interpret system behavior across varying excitation frequencies, and validate theoretical predictions with experimental observations.(PI 1.1.2, PI 2.1.3,PI 2.4.4, PI 4.3.1)*	
03.	**Damped Vibration Analysis** ***Learning Objective:*** *To get acquainted with theoretical and experimental techniques to analyse damped vibrations and estimate the damping coefficient in mechanical systems.*	**06**
	Self-Learning Topics: *Fundamentals and basic concepts of vibrations and damping methods.*	
	Theme for conducting Experiment: 1. Analysis of damped torsional vibration in a single rotor system for damping coefficient estimation. ***Learning Outcome:*** *A learner will be able to* *LO 3.1: Analyze damped torsional vibration in single rotor systems using theoretical models and experimental techniques to estimate damping coefficients, validate dynamic behavior through time-*	

	response data, and collaboratively present accurate conclusions through effective documentation and presentations. (PI 1.1.2, PI 2.3.1, PI 4.1.4, PI 8.1.2, PI 9.1.2)	
04.	**Modern Tools & Computational Analysis** ***Learning Objective:*** *Apply experimental and simulation-based techniques to analyse vibration characteristics of beams under various boundary conditions.*	**06**
	Self-Learning Topics: *Fundamentals and basic concepts of vibrations and basic knowledge of computation methods.*	
	Theme for conducting Experiment: 1. Experimental investigation of free vibration characteristics of a beam using modal testing with an impact hammer. ***Learning Outcome:*** *A learner will be able to* *LO 4.1:Use experimental modal analysis techniques with modern instrumentation (e.g., impact hammer and data acquisition systems) to determine natural frequencies and mode shapes of beams under various boundary conditions, and collaborate effectively to analyze results and document findings through technical reports.(PI 2.4.1, PI 4.1.3,PI 4.3.1, PI 5.2.2, PI 8.1.2, PI 9.1.2)*	
	Theme for conducting Experiment: 2. Simulation-based vibration Analysis of Beams with Various Boundary Conditions using a computational method. ***Learning Outcome:*** *A learner will be able to* *LO 4.2: Apply computational tools to simulate free vibration behavior of beams with different boundary conditions, interpret simulation results to extract mode shapes and natural frequencies, and document outcomes through collaborative reporting and technical presentations.(PI 2.3.1, PI 4.1.3, PI 4.3.1, PI 5.2.2, PI 8.1.2, PI 9.2.2)*	
05.	**Static and Dynamic balancing** ***Learning Objective:*** *To get acquainted with theoretical and experimental principles of static and dynamic balancing and determine the optimal position and magnitude of counterweights in rotating systems.*	**04**
	Self-Learning Topics: *Length diagram, force polyfon and couple polygon*	

	Theme for conducting Experiment: 1. Experimental determination of counterweight position for static and dynamic balancing of rotating masses ***Learning Outcome:*** *A learner will be able to* *LO 5.1:Analyze static and dynamic balancing of rotating masses using theoretical and experimental approaches, compute the magnitude and angular position of counterweights, and work collaboratively to conduct tests and communicate findings through structured technical documentation.* *(PI 1.1.2, PI 1.4.1, PI 2.1.2, PI 2.1.4, PI 4.1.3, PI 4.3.1, PI 8.1.2, PI 9.1.2)*	
	Total	**30**

Performance Indicators:

P.I. No.	**P.I. Statement**
1.1.2	Apply advanced mathematical techniques to model and solve mechanical engineering problems
1.3.1	Apply fundamental engineering concepts to solve engineering problems
1.4.1	Apply Mechanical engineering concepts to solve engineering problems.
2.1.3	Identify the mathematical, engineering and other relevant knowledge that applies to a given problem
2.1.2	Identify engineering systems, variables, and parameters to solve the problems
2.1.4 (new PI)	Desired inferences need to be drawn from graphical tools/representations of engineering quantities of mechanism.
2.3.1	Combine scientific principles and engineering concepts to formulate model/s (mathematical or otherwise) of a system or process that is appropriate in terms of applicability and required accuracy.
2.4.1	Apply engineering mathematics and computations to solve mathematical models.
2.4.4	Extract desired understanding and conclusions consistent with objectives and limitations of the analysis.
4.1.3	Apply appropriate instrumentation and/or software tools to make measurements of physical quantities
4.1.4	Establish a relationship between measured data and underlying physical principles.
4.3.1	Use appropriate procedures, tools and techniques to conduct experiments and collect data
5.2.2	Demonstrate proficiency in using discipline-specific tools.

8.1.2 Implement the norms of practice (e.g. rules, roles, charters, agendas, etc.) of effective team work, to accomplish a goal.

9.1.2 Produce clear, well-constructed, and well-supported written engineering documents

Course Outcomes: A learner will be able to -

1. Evaluate the dynamic response of undamped vibration systems under different excitation conditions. *(LO 1.1, LO 1.2, LO 1.3, LO 2.1, and LO 2.2)*
2. Analyse the response of mechanical systems with damping technique. *(LO 3.1)*
3. Use modern engineering tools to capture and analyse vibration data of the mechanical system. (*LO 4.1 and LO 4.2)*
4. Determine counterweight positions for effective static and dynamic balancing of rotating systems. *(LO 5.1)*

CO-PO Mapping Table with Correlation Level

CO ID	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MELBC506.1	3	3	--	3	--	--	--	2	2	--	--
MELBC506.2	2	2	--	2	--	--	--	2	2	--	--
MELBC506.3	--	3	--	3	2	--	--	2	2	--	--
MELBC506.4	3	3	--	3	3	--	--	2	2	--	--
Average	**3**	**3**	--	**3**	**3**	--	--	**2**	**2**	--	--

NOTE: CO can be mapped to PO at level 3 if at least two PIs are associated with that CO; otherwise, it can be mapped at level 2.

Text Books :

1. Engineering Vibrations, Daniel J. Inman., 3rd Edition, 2009 Pearson Education.
2. Mechanical Vibrations, G. K. Groover , 8th Edition, 2009 Nem Chand & Bros.
3. Mechanical Vibrations, Singiresu S. Rao, 6th Edition, 2018 Pearson Education.

Reference Books :

1. Introductory Course on Theory and Practice of Mechanical Vibration, Rao, J.S. and Gupta, K., 2004, New Age International Pvt. Ltd.
2. Theory of Vibration with Applications, Thomson, W.T., 1990, CBS Publishers, New Delhi

Other Resources :

1. NPTEL :: Mechanical Engineering - Mechanical Vibrations
https://archive.nptel.ac.in/courses/112/103/112103111/

IN-SEMESTER ASSESSMENT (25 MARKS)

Continuous Assessment (25 Marks)

Performance based on experiment (Marks will be awarded to students based on experiment performance with proper understanding)	:	15 Marks
An oral will be conducted based on each experiment	:	05 Marks
Regularity and Active Participation	:	05 Marks

END SEMESTER EXAMINATION (25 MARKS)

- Students will be randomly allocated an experiment from the list of laboratory exercises and will be asked to write appropriate procedure, observation and observation table if required for the same. The experiment procedure is checked by the examiners (Internal and External) and evaluated out of 05 Marks.
- The students will be allocated 1 hour to complete the execution. The students are required to perform the given experiment complete calculation and draw graph if required. Then students required to write conclusion and inferences drawn from results. The experimental performance will be checked by both the examiners for its correctness. The weightage is 10 Marks.
- Students will then be appearing for Oral in front of both Internal and External examiners. The weightage of Oral will be of 10 Marks

  Two examiners, one Internal and one External will do the evaluation.

Course Type	Course Code	Course Name	Credits
LBC	MELBC507	FLUID MECHANICS & MACHINERY LABORATORY	02

Examination Scheme		
Continuous Assessment	**End Semester Exam (ESE)**	**Total**
25	25	50

Pre-requisite:

1. ESC101 Engineering Mechanics
2. PCC301 Engineering Mathematics-III

Program Outcomes addressed:

1. PO1: Engineering knowledge
2. PO2: Problem analysis
3. PO4: Conduct investigations of complex problems
4. PO6: The Engineer and The World
5. PO8: Individual and Collaborative teamwork.

Course Objectives:

1. To analyze fluid properties, dynamics, and flow phenomena for effective engineering design and analysis.
2. To acquaint with the implementation of the continuity equation, discharge flow calculations, major and minor losses in pipes, and the concept of hydraulic gradient energy.
3. To familiarize with the performance characteristics of pumps and turbines through theoretical understanding and practical applications.

Module	Details	Hrs.
	Course Introduction This course aims to develop a strong foundation in fluid mechanics and hydraulic machinery, essential for analyzing and designing mechanical engineering systems. Students will comprehend fluid behavior, differentiate flow patterns, and evaluate forces acting on moving fluids. The course will also examine hydraulic turbines, pumps, and pumping systems, analyze their characteristics, and assess cavitation effects and pipe losses. By the end of this course, students will be able to apply these concepts to optimize fluid transport systems in various engineering applications.	**01**
01.	**Fluid Mechanics** ***Learning Objective:*** - *To demonstrate Bernoulli equation and its application to measurement of flow using different equipment.* - *To introduce various types of pipe losses and guide the analysis of velocity profiles in a pipe.*	**09**

	Contents: **Experiment:** 1. Verification of Bernoulli's Equation 2. Determination the friction factor in Pipes 3. Determination of major and minor losses in Pipe systems	
	Self-Learning Topics:	
	Learning Outcomes: *A learner will be able to* *LO 1.1: Apply mathematical and scientific principles to analyze and validate Bernoulli's equation, interpreting its practical implications in fluid flow systems. (PI 1.1.1, 1.2.1, 2.1.1, 2.3.1, 4.1.1, 6.1.1)* *LO 1.2: Apply fluid mechanics principles to evaluate and compare Bernoulli's equation in different pipe flow conditions, considering energy loss and system efficiency. (PI 1.3.1, 1.4.1, 2.2.3, 2.3.2, 4.1.3, 6.1.2)* *LO 1.3: Identify and analyze the factors influencing friction factor and flow losses in pipe systems, and compare different approaches for loss minimization. (PI 2.1.2, 2.2.4, 4.3.1, 6.2.1)* *LO 1.4: Conduct investigations to determine major and minor losses in pipe systems, validate results through experimental data, and compare with theoretical models. (PI 1.3.1, 2.3.1, 4.1.1, 4.3.2, 6.2.3)* *LO 1.5: Assess the impact of fluid flow efficiency on energy conservation and sustainable pipeline design, incorporating ethical and environmental considerations. (PI 4.3.4, 6.1.3, 8.1.1, 8.2.1)*	
02.	**Hydraulic Machinery**	**20**
	Learning Objectives: - *Apply various techniques to enhance the performance of turbo machines and analyze their practical applications.* - *Describe the characteristics, components, and working principles of pumps and hydraulic turbines, and differentiate between various types of turbines.*	
	Contents: **Experiments:** 1. Trial on centrifugal pump 2. Trial on reciprocating pump. 3. Trial on Impulse turbine (Pelton Wheel Turbine) 4. Trial on Reaction turbine (Francis Turbine)	
	Self-Learning Topics:	
	Learning Outcomes:	
	A learner will be able to. *LO 2.1: Apply fluid mechanics and thermodynamic principles to evaluate the performance of centrifugal and reciprocating pumps, and turbines. (PI 1.3.1, 1.4.1, 2.1.1, 2.3.1, 4.1.1, 6.1.1)* *LO 2.2: Identify and analyze factors influencing the efficiency and performance of pumps and turbines under varying operating conditions. (PI 2.1.2, 2.2.4, 4.3.1, 6.2.1)*	

	LO 2.3: Conduct experiments to measure and validate the performance of impulse and reaction turbines, and interpret results for optimization. (PI 1.3.1, 2.3.1, 4.1.1, 4.3.2, 6.2.3) *LO 2.4: Investigate the energy transfer process in an impulse turbine and assess its efficiency through experimental trials. (PI 4.3.4, 6.1.3, 8.1.1, 8.2.1)* *LO 2.5: Evaluate the impact of efficient pump and turbine designs in minimizing energy consumption and promoting sustainable water management. (PI 4.3.4, 6.1.3, 8.1.1, 8.2.1)* *LO 2.6: Analyze the sustainability and energy efficiency of reaction turbines in hydraulic power generation applications. (PI 6.1.3, 6.2.3, 8.1.1, 8.2.1)*	
	Total	**30**

Performance Indicators:

P.I. No.	**P.I. Statement**
1.1.1	Apply mathematical techniques such as calculus, linear algebra, and statistics to solve problems.
1.2.1	Apply advanced mathematical techniques to model and solve mechanical engineering problems.
1.3.1	Apply fundamental engineering concepts to solve engineering problems.
1.4.1	Apply Mechanical engineering concepts to solve engineering problems.
2.1.1	Articulate problem statements and identify objectives.
2.1.2	Identify engineering systems, variables, and parameters to solve the problems.
2.2.3	Identify existing processes/solution methods for solving the problem, including forming justified approximations and assumptions.
2.2.4	Compare and contrast alternative solution processes to select the best process.
2.3.1	Combine scientific principles and engineering concepts to formulate model/s (mathematical or otherwise) of a system or process that is appropriate in terms of applicability and required accuracy.
2.3.2	Identify assumptions (mathematical and physical) necessary to allow modelling of a system at the level of accuracy required.
4.1.1	Define a problem, its scope and importance for purposes of investigation.
4.1.3	Apply appropriate instrumentation and/or software tools to make measurements of physical quantities.
4.3.1	Use appropriate procedures, tools and techniques to conduct experiments and collect data
4.3.2	Analyze data for trends and correlations, stating possible errors and limitations.
4.3.4	Synthesize information and knowledge about the problem from the raw data to reach appropriate conclusions
6.1.1	Identify and describe various engineering roles; particularly as pertains to protection of the public and public interest at the global, regional and local level.

6.1.2 Identify risks/impacts in the life-cycle of an engineering product or activity.

6.1.3 Understand the relationship between the technical, socio-economic and environmental dimensions of sustainability.

6.2.1 Interpret legislation, regulations, codes, and standards relevant to your discipline and explain its contribution to the protection of the public.

6.2.3 Apply principles of preventive engineering and sustainable development to an engineering activity or product relevant to the discipline.

8.1.1 Recognize a variety of working and learning preferences; appreciate the value of diversity on a team.

8.2.1 Demonstrate effective communication, problem-solving, conflict resolution and leadership skills.

Course Outcomes: A learner will be able to -

1. Apply fundamental fluid mechanics and thermodynamic principles to analyze Bernoulli's equation, flow patterns, and energy losses in pipe networks for practical engineering applications. (*LO 1.1, LO 1.2, LO 1.3, LO 1.4, LO 1.5*)
2. Identify, calculate, and evaluate major and minor losses in piping systems by conducting experiments and validating results with theoretical models to optimize fluid transport efficiency. *(LO1.2, LO 1.3, LO 1.4, LO 1.5)*
3. Analyze and assess the performance of pumps under varying operating conditions by investigating efficiency factors, energy losses, and sustainability considerations in fluid flow systems. *(LO 2.1, LO 2.2, LO 2.5)*
4. Investigate, evaluate, and optimize the performance of impulse and reaction turbines by conducting experiments, analyzing energy transfer processes, and assessing sustainability in hydraulic power generation. *(LO 2.1, LO 2.2, LO 2.3, LO 2.4, LO 2.5, LO 2.6)*

CO-PO Mapping Table with Correlation Level

CO ID	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MELBC507.1	3	3	--	3	--	3	--	3	--	--	--
MELBC507.2	3	3	--	3	--	3	--	3	--	--	--
MELBC507.3	3	3	--	3	--	3	--	3	--	--	--
MELBC507.4	3	3	--	3	--	3	--	3	--	--	--
Average	**3**	**3**	--	**3**	--	**3**	--	**3**	--	--	--

Text Books :

1. Introduction to Fluid Mechanics & Fluid Machines – Som Biswas, Chakraborty, TMH.
2. Fluid Mechanics & Machinery – R. K. Bansal, Luxmi Publications.
3. Fluid Mechanics & Machinery – C.S.P Ojha, R. Berndtsson, P.N. Chandramouli

Reference Books :

1. Introduction to Fluid Mechanics – Fox & Macdonald, Wiley
2. Fluid Mechanics – Fundamentals & Applications – Cengel & Cimbala, TMH.
3. Fluid Mechanics and Fluid Power Engineering by D S Kumar, S K Kataria & Sons

Other Resources :

1. Virtual Labs: https://eerc03-iiith.vlabs.ac.in/List%20of%20experiments.html

IN-SEMESTER ASSESSMENT (50 MARKS)

Continuous Assessment (25 Marks)

Performance based on experiment (Marks will be awarded to students based on experiment performance with proper understanding)	:	15 Marks
An oral will be conducted based on each experiment	:	05 Marks
Regularity and Active Participation	:	05 Marks

END SEMESTER EXAMINATION (25 MARKS)

- Students will be randomly allocated an experiment from the list of laboratory exercises and will be asked to write appropriate procedure, observation and observation table if required for the same. The experiment procedure is checked by the examiners (Internal and External) and evaluated out of 05 Marks.
- The students will be allocated 1 hour to complete the execution. The students are required to perform the given experiment complete calculation and draw graph if required. Then students required to write conclusion and inferences drawn from results. The experimental performance will be checked by both the examiners for its correctness. The weightage is 10 Marks.
- Students will then be appearing for Oral in front of both Internal and External examiners. The weightage of Oral will be of 10 Marks

  Two examiners, one Internal and one External will do the evaluation.

Course Type	Course Code	Course Name	Credits
LBC	MELBC508	COMPUTATIONAL LABORATORY	01

Examination Scheme		
Continuous Assessment	**End Semester Exam (ESE)**	**Total**
25	25	50

Pre-requisite :

1. MEPCC301 - Engineering Mathematics-III
2. MEPCC302 - Mechanics of Solids
3. MEPCC407 - Thermal Engineering

Program Outcomes addressed :

1. PO2: Problem analysis
2. PO3: Design/development of solutions
3. PO4: Conduct investigations of complex problems
4. PO5: Engineering tool usage
5. PO8: Individual and Collaborative Team work
6. PO9: Communication

Course Objectives:

1. Equip students with a solid understanding of FEA and CFD principles, focusing on geometry creation, meshing, boundary conditions, and solver settings.
2. Guide students through the application of meshing techniques to ensure accurate and reliable simulation results.
3. Provide hands-on experience with industry standard tools for various analyses, including static, modal, thermal, transient, and fluid flow.
4. Familiarize students to the post-processing techniques in order to analyse and validate simulation results and further optimize designs.

Module	Detailed Contents	Hrs
	Course Introduction This course introduces students to the fundamentals of Finite Element Analysis (FEA) and Computational Fluid Dynamics (CFD) using industry standard software. Students will learn to create geometry, generate meshes, set boundary conditions, and configure solvers. Through practical tasks, they will perform static, modal, thermal, and fluid flow analyses for various engineering problems. The course emphasizes understanding mesh quality, analysing simulation results, and applying post-processing techniques to evaluate stress, deformation, and flow performance. By the end, students will be equipped to use software based tools to solve real-world problems and optimize engineering designs.	**01**

01.	***Learning Objective/s:*** *To utilize appropriate software for geometry creation, meshing, and boundary conditions, while ensuring suitable element selection and mesh quality for static structural analysis.*	**07**
	To get acquainted to Essentials of FEA covering the following topics: *Introduction to FEA Software Interface and Geometry Modelling Tools* *Types of Elements in FEA (1D, 2D, 3D, Difference between surface elements and solid elements)* *Selection of Element Types* *Understanding Mesh Quality Metrics* *Defining Boundary Conditions (Supports, Loads) and Material Properties*	
	Tasks: i. 2D/3D geometry creation using industry standard geometry modelling tool. ii. Generation of solid and surface elements. iii. Generation of structured and unstructured mesh for a 1D and 2D element. iv. Meshing and element size refinement for a 2D/3D solid object (e.g., bracket or plate). v. Setting up boundary conditions and loads for a static structural analysis.	
	Self-Learning Topics: *Advanced Mesh Refinement and Optimization in ANSYS for accurate Structural Analysis.*	
	Learning Outcomes : *A learner will be able to* *LO 1.1: Apply suitable industry standard modelling tool for geometry creation and model setup. (PI 3.1.1, PI 5.1.1, PI 5.2.1, PI 9.3.1)* *LO 1.2: Identify and select appropriate FEA element types for various analysis scenarios. (PI 2.3.1, PI 4.1.4, PI 5.2.1, PI 8.2.1)* *LO 1.3: Create mesh and validate mesh quality metrics for accurate simulations. (PI 2.4.2, PI 4.3.3, PI 5.3.2, PI 9.1.1)* *LO 1.4: Apply boundary conditions and material properties to engineering models to solve structural analysis problems. (PI 2.3.1, PI 2.4.4, PI 3.3.1, PI 8.3.1)*	
02.	***Learning Objective/s:*** *To explore solver settings for static, modal, thermal, and transient analyses, and perform post-processing to interpret stress, deformation, and safety factors.*	**08**
	To apply the FEA based commercial software package in order to solve problems covering the following topics: *Types of Solvers and Solver Settings* *Analysis Types: Static, Modal, Thermal, and Transient* *Convergence criteria* *Post-Processing: Stress Distribution, Deformation, Factor of Safety, Iso-surface and Contour Visualization*	

	Tasks: i. Static structural analysis of a stepped bar. ii. Modal analysis to determine the natural frequencies of a simple structure (e.g., a bridge or plate). iii. Structural buckling analysis of a slender column under axial compression. iv. Stress analysis of a pressure vessel with internal pressure.	
	Self-Learning Topics: *Understanding Failure Modes through structural analysis in ANSYS*	
	Learning Outcomes: *A learner will be able to* *LO 2.1: Identify and apply the appropriate solver and solver settings for static, modal and transient analyses. (PI 3.3.1, PI 4.1.2, PI 5.2.1)* *LO 2.2: Apply convergence criteria to ensure the accuracy and stability of finite element analysis (FEA) simulations across various analysis types. (PI 2.4.2, PI 4.3.2, PI 5.3.2)* *LO 2.3: Interpret and evaluate post-processing results, including stress distribution, deformation, and factor of safety, to assess the structural integrity of engineering models. (PI 2.4.4, PI 4.3.1, PI 8.3.1)* *LO 2.4: Utilize visualization techniques such as iso-surfaces and contour plots to analyze simulation outputs and extract meaningful engineering insights. (PI 4.3.3, PI 5.1.1, PI 9.3.1)*	
03.	***Learning Objective/s:*** *To use industry standard software tool to create geometries, generate grids with appropriate element types, and evaluate mesh quality and connectivity for accurate simulations.*	**06**
	To get acquainted to Essentials of CFD covering the following topics: *Introduction to CFD Software Interface and Geometry Modelling Tools* *Types of Elements and Grid generation* *Types of Mesh* *Mesh Quality Metrics* *Mesh Connectivity Metrics* *Boundary Conditions and Solvers*	
	Tasks : i. 2D/3D geometry creation using Design Modeler and/or Space Claim ii. Unstructured mesh generation for a Y-section iii. Structured mesh generation for the study of external flow over a NACA aerofoil iv. Grid generation for 3D domain using Fluent meshing. v. Apply different types of boundary conditions like velocity, mass flow rate, pressure, pressure far field, temperature, heat flux, stationary wall, rotating wall, periodic and symmetry to suitable fluid and thermal problem.	
	Self-Learning Topics: *Optimizing Mesh Quality for accurate CFD Simulations*	

	Learning Outcomes : *A learner will be able to* *LO 3.1: Construct 2D and 3D geometries using industry standard software for engineering simulations. (PI 3.1.1, PI 5.1.1, PI 5.2.1, PI 9.3.1)* *LO 3.2: Identify and select appropriate fluid and thermal element types for various analysis scenarios. (PI 2.3.1, PI 4.1.4, PI 5.2.1, PI 8.2.1)* *LO 3.3: Develop an unstructured and structured mesh using appropriate meshing techniques and validate mesh quality metrics for accurate simulations. (PI 2.4.2, PI 4.3.3, PI 5.3.2, PI 9.1.1)* *LO 3.4: Apply boundary conditions and material properties to engineering models to solve fluid and thermal analysis problems. (PI 2.3.1, PI 2.4.4, PI 3.3.1, PI 8.3.1)*	
04.	***Learning Objective/s:*** *To set up solver settings, initialization, and turbulence models, and apply post-processing techniques to export data in different formats for analysis.*	**08**
	To apply the CFD based commercial software package in order to solve problems covering the following topics: *Solver settings, Initialization, Residue, Report monitors* *Types of Turbulence Models* *Post Processing, Iso-surface Visualization, Cut Plane Visualization, 3D Field Visualization, Data Export in CSV format*	
	Tasks: i. Laminar and turbulent flow over an aerofoil at different angles of attack ii. Computational analysis of Jet surface interaction iii. Computational analysis of shell and tube heat exchanger iv. Transient study of phase change characteristics of an ice block.	
	Self-Learning Topics: *Simulation of Complex Fluid-Structure Interactions*	
	Learning Outcomes : *A learner will be able to* *LO 4.1: Configure solver settings, initialization, and report monitors to optimize fluid flow simulations. (PI 2.2.4, PI 4.1.2, PI 5.2.1)* *LO 4.2: Apply different turbulence models to simulate laminar and turbulent flow conditions accurately. (PI 2.4.2, PI 4.1.4, PI 5.3.2)* *LO 4.3: Visualize simulation results using iso-surface, cut-plane, and 3D field visualization techniques. (PI 4.3.2, PI 5.2.1, PI 9.3.1)* *LO 4.4: Export simulation data in CSV format for further analysis and reporting. (PI 4.3.3, PI 8.3.1, PI 9.1.1)*	
	Total	**30**

Performance Indicators:

P.I. No.	P.I. Statement
2.2.4	Compare and contrast alternative solution processes to select the best process.
2.3.1	Combine scientific principles and engineering concepts to formulate model/s (mathematical or otherwise) of a system or process that is appropriate in terms of applicability and required accuracy.
2.4.2	Produce and validate results through skilful use of contemporary engineering tools and models.
2.4.4	Extract desired understanding and conclusions consistent with objectives and limitations of the analysis.
3.1.1	Recognize that need analysis is key to good problem definition.
3.3.1	Apply formal decision-making tools to select optimal engineering design solutions for further development.
4.1.2	Examine the relevant methods, tools, and techniques of experiment design, system calibration, data acquisition, analysis, and presentation.
4.1.4	Establish a relationship between measured data and underlying physical principles.
4.3.1	Use appropriate procedures, tools, and techniques to conduct experiments and collect data.
4.3.2	Analyze data for trends and correlations, stating possible errors and limitations.
4.3.3	Represent data (in tabular and/or graphical forms) so as to facilitate analysis and explanation of the data and drawing of conclusions.
5.1.1	Identify modern engineering tools such as computer-aided drafting, modeling, and analysis; techniques and resources for engineering activities.
5.2.1	Identify the strengths and limitations of tools for acquiring information, modeling and simulating, monitoring system performance, and creating engineering designs.
5.3.2	Verify the credibility of results from tool use with reference to the accuracy and limitations, and the assumptions inherent in their use.
8.2.1	Identify tenets of the ASME professional code of ethics.
8.3.1	Examine and apply moral & ethical principles to known case studies.
9.1.1	Implement the norms of practice (e.g., rules, roles, charters, agendas, etc.) of effective teamwork to accomplish a goal.
9.3.1	Present results as a team, with smooth integration of contributions from all individual efforts.

Course Outcomes: A learner will be able …….

1. To create accurate engineering models and develop high-quality meshes for simulation. *(LO 1.1, LO 1.3, LO 3.1, LO 3.3)*
2. To select and assign appropriate materials, boundary conditions, and element types to solve various analysis problems. *(LO 1.2, LO 1.4, LO 3.2, LO 3.4)*
3. To set up and optimize solver configurations and convergence criteria for both structural and fluid flow simulations. *(LO 2.1, LO 2.2, LO 4.1, LO 4.2)*
4. To interpret simulation outputs using advanced visualization techniques and generate reports for engineering decision-making. *(LO 2.3, LO 2.4, LO 4.3, LO 4.4)*

CO-PO Mapping Table with Correlation Level

CO ID	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MELBC508.1	--	2	3	--	3	--	--	--	3	--	--
MELBC508.2	--	3	2	2	2	--	--	3	--	--	--
MELBC508.3	--	3	2	3	3	--	--	--	--	--	--
MELBC508.4	--	2	--	3	3	--	--	2	3	--	--
Average	--	**3**	**2**	**3**	**3**	--	--	**3**	**3**	--	--

NOTE: CO can be mapped to PO at level 3 if at least two PIs are associated with that CO; otherwise, it can be mapped at level 2.

Books :

1. S. Moaveni, *Introduction to Finite Element Analysis Using ANSYS*. Boston, MA: Pearson, 2015.
2. N. S. Gokhale and S. S. Deshpande, *Practical Finite Element Analysis*. Finite to Infinite, 2008.
3. D. L. Logan, *A First Course in the Finite Element Method*, 6th ed. Boston, MA: Cengage Learning, 2016.
4. H. K. Versteeg and W. Malalasekera, An Introduction to Computational Fluid Dynamics: The Finite Volume Method, 2nd ed. Harlow, UK: Pearson, 2007.
5. J. Blazek, Computational Fluid Dynamics: Principles and Applications, 3rd ed. Amsterdam, Netherlands: Elsevier, 2015.
6. J. D. Anderson, CFD Fundamentals with Applications. New York, NY: McGraw-Hill, 1995.

Reference Books :

1. J. N. Reddy, *An Introduction to the Finite Element Method*, 4th ed. New York, NY: McGraw-Hill, 2019.
2. C. S. Krishnamoorthy, *Finite Element Analysis: Theory and Programming*. New Delhi, India: Tata McGraw-Hill, 1994.
3. B. S. Gupta, *Introduction to Finite Elements in Engineering.* New Delhi, India: Oxford and IBH Publishing, 1991.
4. A. W. Date, *Introduction to Computational Fluid Dynamics.* Cambridge, UK: Cambridge University Press, 2005.
5. K. Muralidhar and T. Sundararajan, *Computational Fluid Flow and Heat Transfer*, 2nd ed. Alpha Science International, 2014.
6. P. Roache, *Verification and Validation in Computational Science and Engineering*. Albuquerque, NM: Hermosa Publishers, 1998.

Other Resources :

1. Basics of Finite Element Analysis - I (IIT Kanpur), Prof. Nachiketa Tiwari

   Link: https://nptel.ac.in/courses/112104193
2. Ansys Training: Introduction to Ansys DesignModeler

   Link:https://www.ansys.com/training-center/course-catalog/structures/introduction-to-ansys-designmodeler

3. Basics of Finite Element Analysis – II, Prof. Nachiketa Tiwari
   Link: https://nptel.ac.in/courses/112104205
4. edX - A Hands-on Introduction to Engineering Simulations (Cornell University)
   Link: https://www.edx.org/learn/engineering/cornell-university-a-hands-on-introduction-to-engineering-simulations
5. NPTEL - Computational Fluid Dynamics (IIT Kharagpur), Prof. S. K. Som
   Link: https://nptel.ac.in/courses/112105254
6. ANSYS Training - DesignModeler (CFD)
   Link: https://www.ansys.com/training-center/course-catalog/fluids/introduction-to-ansys-designmodeler-cfd
7. Udemy - Mastering ANSYS CFD
   Link: https://www.udemy.com/course/mastering-ansys-cfd/

IN-SEMESTER ASSESSMENT (25 MARKS)

1. **Continuous Assessment (25 Marks)**

Suggested breakup of distribution

- Performance based on completion of task (Marks will be awarded to students based on task performance with proper understanding) : 15
- Course Project (max 4 students) to demonstrate concept : 05
  1. Finite element analysis of any structural system
  2. CFD analysis of any fluid or thermal system
- Regularity and Active Participation : 05

END SEMESTER EXAMINATION (25 MARKS)

Students will be assessed based on three parameters:

- Finite Element Analysis and Computational Fluid Dynamics concepts / understanding
- Practical performance
- Oral

- Students will be randomly allocated a task from the list of tasks performed during the semester (or any other similar task) and will be asked to write brief procedure related to the execution of the task including the diagram and/or calculation if any. The procedure and/or calculation is checked by the examiners (Internal and External) and evaluated out of 5 Marks.
- Then the student will be allowed to complete the task.
- The students will be allocated 1 hour to complete the execution. The students are required to complete the given task and write conclusion for the simulation result and compare it with mathematical calculation, if any. The completed task will be checked by both the examiners for its correctness. The weightage is 10 Marks.
- Students will then be appearing for Oral in front of both Internal and External examiners. The weightage of Oral will be of 10 Marks

Two examiners, one Internal and one External will do the evaluation.

Course Type	Course Code	Course Name	Credits
AEC	AEC502	PROFESSIONAL COMMUNICATION & ETHICS-2	02

Examination Scheme					
Distribution of Marks			Exam Duration (Hrs.)		Total Marks
In-semester Assessment		End Semester Examination (ESE)			
Continuous Assessment	Mid-Semester Exam (MSE)		MSE	ESE	
50	--	--	--	--	50

Pre-requisite:

1. Satisfactory completion of AEC201 course work/ a similar level of course in Semester 2/ previous semesters

Program Outcomes addressed:

1. PO7 : Ethics
2. PO8 : Individual and Teamwork
3. PO9 : Communication
4. PO11: Life-long learning

Course Objectives:

1. To inculcate in students professional and ethical attitude, effective communication skills, team work, multidisciplinary approach and an ability to understand engineers' social responsibility.
2. To provide students with an academic environment where they will be aware of the excellence, leadership and lifelong learning needed for a successful professional career.
3. To create awareness about professional ethics and codes of professional practice and leadership.
4. To prepare students for a successful career that meets the global industrial and corporate requirement, provide students to work on multidisciplinary projects as part of different teams to enhance their team building capabilities like leadership, motivation, teamwork, etc.

Module	Details	Hrs.
	Course Introduction The curriculum of Professional Communication and Ethics-2 is designed to build up a proficient and ethical approach among the students in the professional engineering environment. Their capacity and skills of effective oral and written communication will be enhanced with the various practical activities that have been designed within the course. Through practical sessions will supplement the learner's interactive competence and confidence to respond appropriately and creatively to the implied challenges of the global industrial and corporate	**01**

	requirements. It will further inculcate within the budding engineer the social commitment of as responsible technical citizens.	
01.	**ADVANCED TECHNICAL WRITING:PROJECT/PROBLEM BASED LEARNING** ***Learning Objective:*** *To discern and develop an effective style of writing important technical/business documents.* *To understand the dynamics of professional communication and to develop creative and efficient presentation skills.* *To understand the importance of integrity and personal and professional code of ethics*	**04**
	Contents: **Contents:** **1.1 Writing Reports** o **Classification of reports on the basis of**: Subject Matter, Time Interval, Function, Physical Factors. o **Parts of a long formal report**: Front Matter, Main Body and Back Matter. o **Language and style of Reports:** Grammar, Tone, Style, Vocabulary, Format of the report from title page to appendices. **1.1 Definition, purpose and types of proposals** : **Parts of a Proposal:** Elements, Scope and Limitations, Conclusion o Technical Proposal. o Business Plan. **1.3 Technical paper writing. (APA/IEEE)** **Parts of a Research paper**: o Title Page o Abstract, o Introduction o Problem Statement/Hypothesis o Research methods, o Data Search (Primary/Secondary) o Quantitative/ Qualitative Analysis o Discussion, o Delimitations, o future scope and o References. o Appendix o Acknowledgement **1.4 Presenting and Publishing a Research Paper (Significance as a professional)**	
	Self-Learning Topics: ***Read and summarise a business plan by any industry expert.*** ***Read an academic research paper and look for gaps in the research area.***	
	Learning Outcomes: *The learner will be able to* *LO 1.1: Objectively state the purpose of research, research methodology and apply the knowledge while writing an academic paper in IEEE format.(9.1.1,9.1.3,,11.1.1,11.1.2,11.3.1)*	

	LO 1.2: Present research paper effectively in a time bound manner to everyone's understanding (8.3.1, 9.1.3, 9.2.2, 9.2.3) *LO 1.3: Demonstrate the ability use critical thinking to find gaps in research and present it. (8.2.1, 11.1.2, 11.3.1)* *LO 1.4: Apply gained knowledge for continuous improvement for professional growth.(11.1.1)*	
02.	**EMPLOYABILITY SKILLS** ***Learning Objective:*** *To increase the ability to write constructive documents such as the SOP* *To instil productive and efficient skills for the workplace.* *To facilitate fluent and precise presentation skills, in professional situations with and without the use of ICT tools*	**02**
	Contents: **2.1 Statement of Purpose** o Purpose o Elements of SOP o Structure o Tips for writing effective SOP. **2.2 Verbal Aptitude Tests** modeled on CAT,GRE,GMAT,IELTS **2.3 Group Discussions** :Purpose, parameters of evaluating, Types of GDs (Traditional, Case-based & Role Plays), GD Etiquettes **2.4 Personal Interviews:** Preparation, Types of questions, Types of interviews and modes of interviews. Types: Structured, Stress, Behavioural, Problem Solving & Case-based, Modes of Interviews: Face-to-face (One-to one and Panel) Telephonic, Virtual	
	Self-Learning Topics: ***Watch recordings of professional interviews from online resources.(ex:Civil Service interviews), IIM and UPSC GDs***	
	Learning Outcomes: *A learner will be able to* *LO 2.1*: *Apply knowledge for continuous improvement and professional growth. (11.1.1.)* *LO 2.2: Demonstrate effective communication and arrive at decisions through strong leadership skills and teamwork. (7.1.1,8.1.2,8.2.1,8.2.3, 8.2.4, 8.3.1,9.2.2)* *LO 2.3*: *Effectively prepare for competitive exams through mock tests* (*8.2.1,11.1.1)* .	
03.	**TECHNICAL/BUSINESS PESENTATIONS** ***Learning Objective:*** *To prepare academic and technical presentation slides and to present it to the audience.* *To be able to engage the audience during a presentation.*	**02**

	To comprehend the presentation skills and etiquette. *To gain teamwork skills and problem solving skills*	
	Contents: **3.1 Effective Presentation Strategies:** o Purpose of a presentation, o Understanding the audience, location and the event, o Arranging the material, structuring the presentation, o Making effective slides and platform skills. **3.2 Group Presentations:** o Sharing responsibility in a team (Delegation) o Creating the content together (Uniformity) o Transition phases and Coordination. **3.3 Individual Presentations:** o Introduction of Self and Topic o Understanding the audience, building rapport o Time Management o End with Q n A, Feedback	
	Self-Learning Topics: *Watch YouTube videos of presentations like TED TALKS on motivational topics*	
	Learning Outcomes: *A learner will be able to* *LO 3.1: Apply oral and written communication skills effectively and ethically during group discussions. (7.1.1, 7.2.2, 8.2.1, 9.2.1, 9.2.2.)* *LO 3.2: Demonstrate presentation skills and leadership skills through team work and management (8.1.2, 8.2.1,8.3.1, 9.3.2)* *LO 3.3: Exhibit impressive presentation etiquette with appropriate ethical standards. (7.1.1,7.3.1,9.2.2)*	
04.	**INTERPERSONAL SKILLS** ***Learning Objectives:*** 1. *To help budding engineers understand the importance of interpersonal skills for personal and professional growth.* 2. *To aid the learner in understanding the significance of employment generation and the need for it.*	**03**
	Contents: **4.1. Interpersonal Skills:** o Emotional intelligence, o Leadership o Conflict Management, o Negotiation & Conflict Resolution o Time management, o Assertiveness o Decision making. **4.2. Start- Up Skills:** o Financial Literacy o Risk Assessment o Data Analysis.	

	Self-Learning Topics: Collect information on some failed startups. Assess and analyse the reasons for their failure.	
	Learning Outcomes: *A learner will be able to* *LO 4.1: Apply the learned interpersonal skills in presenting posters, business plans and proposals. (7.1.1, 7.2.2, 7.3.1,8.1.2,8.3.1,9.3.2, 11.1.1)* *LO 4.2: Participate in a well-organized and constructive GD. (7.2.2, 7.3.1,8.2.1, 8.3.1)* *LO 4.3: Generate a business plan for a startup. (8.2.1,11.1.1,11.1.2)*	
05.	**CORPORATE ETHICS** ***Learning Objective/s:*** 1. *To aid the learner to differentiate between various codes of conduct and ethics in the social and professional world.* 2. *To enforce the significance of ethical citizenry.* 3. *To generate awareness on the importance of IPR and its consequences*	**02**
	Contents: **5.1. Intellectual Property Rights : Significance, Duration, Laws** o Copyrights o Trademarks o Patents o Geographical Indication o Industrial Designs o Trade Secrets **5.2 Gender Equity & Inclusivity at the Work Place** o Study on Cases related to Gender Equity in India & Global o Corporate Social Responsibility o Inclusivity at the work place	
	Self-Learning Topics: Read a biography on a Business Leader/Philanthropist	
	Learning Outcomes : *A learner will be able to* *LO 5.1: Utilise moral and ethical principles in their professional and social life (7.1.1, 7.2.2, 7.3.1)* *LO 5.2: Critically evaluate various socioeconomic, gender issues of discriminatory nature (7.1.1, 7.2.2,7.3.1, 8.1.1, 8.1.2)* *LO 5.3: Employ the awareness of IPR to avoid unethical practices in their professional life (7.1.1,7.2.2, 8.2.1, 8.2.2, 11.1.1)*	
06.	**Activities for Ability Enhancement (Practical Sessions):**	**30**
	Contents: *1. Prepare a TRIFOLD POSTER on any one Technical problem with solutions for the same and present it. (Team of 4/ Trifold (10 M)+ Presentation + Group Dynamics (5M)* *2. Write a research paper on the given topic in IEEE format (5M)* *3. Prepare an SOP for admission procedure in a reputed university.(5M)*	

	4. Participate in GDs on given topic followed by Mock Interview((5M) *5.Attempt Verbal Aptitude Tests(5M)* *6. Assess and analyse a Case Study on the topic on Gender Equity & Inclusivity; Generate a solution based article and present before an audience (10M)*	
	Activities will start in the inverted pyramid, viz., with group activities first so as to build confidence and ending with solo presentations in the form of research paper presentation or Gender Equity presentation. *Group Discussion, Interview Skills, Presentation skills will have at least three mock drills before the final assessment of the same.* *Rigorous development of the English language, social and professional etiquette will be the praxis*	
	Course Conclusion	**01**
	Total	**45**

Performance Indicators:

P.I. No.	**P.I. Statement**
7.1.1	Identify situations of unethical professional conduct and propose ethical alternatives
7.2.2	Examine and apply moral & ethical principles to known case studies
7.3.1	Apply and exhibit universal human values and a diverse and inclusive mind-set, free of discrimination
8.1.1	Recognize a variety of working and learning preferences; appreciate the value of diversity on a team
8.1.2	Implement the norms of practice (e.g. rules, roles, charters, agendas, etc.) of effective team work, to accomplish a goal.
8.2.1	Demonstrate effective communication, problem-solving, conflict resolution andleadership skills
8.2.2	Treat other team members respectfully
8.2.3	Listen to other members
8.2.4	Maintain composure in difficult situations
8.3.1	Present results as a team, with smooth integration of contributions from all individual efforts
9.1.1	Read, understand and interpret technical and non-technical information
9.1.3	Create flow in a document or presentation - a logical progression of ideas so that themain point is clear
9.2.1	Listen to and comprehend information, instructions, and viewpoints of others
9.2.2	Deliver effective oral presentations to technical and non-technical audiences
9.2.3	Apply efficient and effective communication, keeping in mind the diversity and uniqueness in the team.
9.3.2	Use a variety of media effectively to convey a message in a document or a

	presentation
11.1.1	State the rationale for the requirement for continuing professional development
11.1.2	Identify deficiencies or gaps in knowledge and demonstrate an ability to source information to close this gap
11.3.1	Source and comprehend technical literature and other credible sources of information

Course Outcomes: A learner will be able to -

1. Communicate effectively and ethically in both oral and written forms which will in turn provide a solid foundation for their future managerial roles. (*LOs 1.1, 1.2, 1.4, 2.2, 3.1, 3.2, 4.1, 4.2, 5.1)*
2. Possess the skill set required for successful employability and exhibit leadership skills. (*LOs 2.1, 2.2, 3.2, 4.2, 4.3)*
3. Develop an acumen to prepare for and give various competitive exams and emerge successful in group discussions and conduct healthy debates. (*LOs 2.1, 2.2, 2.3, 4.2)*
4. Develop creative thinking and demonstrate knowledge of professional and personal etiquettes & ethics, such as diversity and inclusivity, in the global environment. (*LOs 1.3, 3.2, 3.3, 4.3, 5.1, 5.2, 5.3)*

CO-PO Mapping Table with Correlation Level

CO ID	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
AEC502.1	--	--	--	--	--	--	3	3	3	--	3
AEC502.2	--	--	--	--	--	--	3	3	3	--	2
AEC502.3	--	--	--	--	--	--	2	3	2	--	2
AEC502.4	--	--	--	--	--	--	3	3	3	--	3
Average	**--**	**--**	**--**	**--**	**--**	**--**	**3**	**3**	**3**	**--**	**3**

Reference Books:

1. Arms, V. M. (2005). *Humanities for the engineering curriculum: With selected chapters from Olsen/Huckin:*
2. *Technical writing and professional communication, second edition*. Boston, MA: McGraw-Hill.
2. Bovée, C. L., &Thill, J. V. (2021).

3. *Business communication today*. Upper Saddle River, NJ: Pearson.
4. Butterfield, J. (2017). *Verbal communication: Soft skills for a digital workplace*. Boston, MA: Cengage Learning.
5. Masters, L. A., Wallace, H. R., & Harwood, L. (2011).*Personal development for life and work*. Mason: South Western Cengage Learning.
6. Robbins, S. P., Judge, T. A., & Campbell, T. T. (2017). *Organizational behaviour*. Harlow, England: Pearson.
7. Meenakshi Raman, Sangeeta Sharma (2004) Technical Communication, Principles and Practice. Oxford University Press
8. Archana Ram (2018) Place Mentor, Tests of Aptitude For Placement Readiness. Oxford University Press
9. Sanjay Kumar &PushpLata (2018). Communication Skills a workbook, New Delhi: Oxford University Press.

Other Resources :

1. NPTEL Course: https://archive.nptel.ac.in/courses/109/104/109104030
   Dept. of Humanities and Social Sciences, IIT Kanpur, A Course on Communication Skills

CONTINUOUS INTERNAL ASSESSMENT (50 Marks)

1. Prepare a TRIFOLD POSTER on any one socio-technical problem with solutions for the same and present it. (Team of 4/ Trifold) (10 M) + Presentation & Group Dynamics. (5M)
2. Write a TECHNICAL research paper on a designated topic in IEEE format. (5M)
3. Prepare an SOP for admission procedure in a reputed university. (5M)
4. Participation in Final GD on concrete/abstract topic followed by Mock Interview. (5M)
5. Verbal Aptitude Tests (5M)
6. Analyse a Case Study on the topic of Gender Equity & Inclusivity (10M)
7. Regularity and Active participation (5M)

Course Type	Course Code	Course Name	Credits
MNP	MEMNP503	MINI PROJECT- 2A	01

Program Outcomes addressed:

1. PO1: Engineering Knowledge
2. PO2: Problem Analysis
3. PO3: Design/Development of Solutions
4. PO4: Conduct Investigations of Complex Problems
5. PO5: Engineering Tool Usage
6. PO6: The Engineer and The World
7. PO7: Ethics
8. PO8: Individual and Collaborative Team work
9. PO9: Communication
10. PO10: Project Management and Finance
11. PO11: Life-Long Learning

Course Objectives:

1. To guide students in identifying societal or research needs and formulating them into problem statements.
2. To facilitate problem-solving in group settings.
3. To apply basic engineering principles to address identified problems.
4. To foster self-learning and research skills.

Course Outcomes:

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

1. Identify problems based on societal or research needs and methodology for solving them.
2. Apply knowledge and skills to solve societal problems collaboratively.
3. Develop interpersonal skills necessary for teamwork.
4. Analyze, verify, and validate results effectively through various methodologies, including, test cases/benchmark data/theoretical/inferences/experiments/simulations, etc.
5. Evaluate the societal and environmental impacts of proposed solutions.
6. Adhere to standard engineering practices.
7. Excel in written and oral communication by technical report writing, oral presentation, and publishing results in
   - Research/white paper/article/blog writing/publication, etc.
   - Business plan for entrepreneurship product creation
   - Patent filing/copyright.
8. Gain technical competencies by participating in competitions, hackathons, etc.
9. Demonstrate lifelong learning capabilities through self-directed group projects.
10. Apply project management principles effectively.

Guidelines for the Mini Project
Mini project may be carried out in one or more form of following: Product preparations, prototype development model, fabrication of set-ups, laboratory experiment development, process modification/development, simulation, software development, integration of software (frontend-backend) and hardware, statistical data analysis, creating awareness in society/environment etc. • Students must form groups of 3 to 4 members either from the same or from different departments.

- Groups should conduct surveys to identify needs and develop problem statements in consultation with faculty.
- An implementation plan in Gantt/PERT/CPM chart format covering weekly activities must be submitted.
- Each group must maintain a logbook to record weekly progress, to be verified by the faculty supervisor.
- Faculty input should emphasize guiding by faculty and self-learning by group members.
- Groups should propose multiple solutions, select the best one in consultation with the supervisor, and develop a working model.
- The solution to be validated with proper justification and report to be compiled in standard format of the Institute. Software requirement specification (SRS) documents, research papers, competition certificates may be submitted as part of annexure to the report.
- With the focus on self-learning, innovation, addressing societal/research/innovation problems and entrepreneurship quality development within the students through the Mini Projects, it is preferable that a single project of appropriate level and quality be carried out in two semesters by all the groups of the students.
- However, based on the individual students or group capability, with the mentor's recommendations, if the proposed Mini Project adhering to the qualitative aspects mentioned above, gets completed in odd semester, then that group can be allowed to work on the extension of the Mini Project with suitable improvements/modifications or a completely new project idea in even semester. This policy can be adopted on a case by case basis.

In-Semester Continuous Assessment and End-Semester Examination Guidelines

- The Head of the Departments will assign a guide to each of the mini-projects and shall form a progress monitoring committee. The guide will carry out weekly monitoring of the project's progress. The committee shall carry out in-semester project evaluation based on presentations with a minimum of two evaluations per semester.
- Assessment will be based on individual contributions, understanding, and responses to questions asked.
- Continuous Assessment marks distribution in semester V (50 marks):
    - 05 marks for the Topic Approval Presentation in front of the progress monitoring committee
    - 15 marks for the Mid-Semester Progress Presentation in front of the progress monitoring committee
    - 25 marks for the Final Report & Presentation
    - 05 marks for Regularity and Active participation
- Continuous Assessment marks distribution in semester VI (50 marks):
    - 15 marks for the In-Semester Two Presentations
    - 05 marks for Participation in Project Competitions, TPP, etc.
    - 25 marks for the Final Report & Presentation
    - 05 marks for Regularity and Active participation

The review/progress monitoring committee will assess projects based on the following criteria.

Semester V:

- Theoretical solution completion, including component/system selection/design of software solution and cost analysis.
- Two reviews will occur:
    - The first review will focus on finalizing the problem statement (topic approval).
    - The second review will centre on finalizing the proposed solution.

Semester VI:

- Expected tasks include procuring components/systems, constructing a working prototype, and validating results based on prior semester work.
- Reviews will be conducted as follows:
  - The first review will assess the readiness to build a working prototype.
  - The second review will involve a poster presentation and demonstration of the working model in the last month of the semester.

In addition to above mentioned points, the following performance criteria shall be included during in-semester continuous assessment:

1. Quality of survey and need identification.
2. Clarity and innovativeness in problem definition and solutions.
3. Requirement gathering via SRS/feasibility study, cost-effectiveness, and societal impact of proposed solutions.
4. Completeness and full functioning of the working model.
5. Effective use of skill sets and engineering norms.
6. Verification & validation of the solutions/test cases.
7. Individual contributions to the group.
8. Clarity in written and oral communication.
9. Participation in technical paper presentation/project competitions/hackathon competitions, etc.

End-Semester Examination in Semester VI (50 marks):

1. Presentation and demonstration to internal and external examiners: 20 marks.
2. Emphasis on problem clarity, innovativeness, societal impact, functioning of the model, skill utilization, and communication clarity: 30 marks.

Course Type	Course Code	Course Name	Credits
HSS	HSS502	Entrepreneurship	02

Examination Scheme					
Distribution of Marks			Exam Duration (Hrs.)		Total Marks
In-semester Assessment		End Semester Exam (ESE)			
Continuous Assessment	Mid-Semester Exam (MSE)		MSE	ESE	
50	--	--	--	--	50

Pre-requisite: NIL

Program Outcomes addressed:

1. PO1: Engineering knowledge
2. PO2: Problem analysis
3. PO3: Design/ Development of Solutions
4. PO6: The Engineer & The World.
5. PO7: Ethics
6. PO10: Project Management & Finance
7. PO11: Life-long learning

Course Objectives:

1. To develop Entrepreneurial mindset amongst the learners.
2. To promote Entrepreneurship as life-skills to improve quality of life, skills of creation and management of entrepreneurial pursuits.
3. To explore paths of the innovation through the creative problem-solving skills
4. To familiarize with the steps involved in 'idea to product' development.
5. To get acquainted with the preparation of pitch at ideation, business idea presentation and funding stages

Module	Details	Hrs
00	**Course Introduction:** This course aims to equip individuals with the knowledge, skills, and mindset needed to identify and pursue new business opportunities. It aims to foster an entrepreneurial culture and mindset to help develop the next generation of entrepreneurs who can create jobs, drive economic growth, and contribute to the society. Entrepreneurship is a life skill that will help an individual succeed in a variety of scenarios, both personal and professional. By its very nature, entrepreneurship is an interdisciplinary field that draws from a range of disciplines, including business, economics, engineering, and social sciences. Some of the key topics covered in Entrepreneurship Course include opportunity recognition, market research, business planning, financing, marketing, and management while emphasizing the development of critical thinking, creativity, risk-taking, and problem- solving skills.	1

1	**Fundamentals of Entrepreneurship**	5-6
	Learning Objectives: • *To gain knowledge about the concepts and principles of entrepreneurship, including opportunity recognition and value creation.* • *To develop an entrepreneurial mindset and skills that will enable them to identify, evaluate, and pursue viable business opportunities with confidence.*	
	Contents: Introduction to Entrepreneurship, Entrepreneurial Mindset, Opportunity Identification, Market Analysis & Customer Research, Business Models & Go-to-Market, Funding and Financial Management, Marketing Aspects, Scaling the Venture and Growth Strategies: *Note:* A real life case study covering key elements of the module shall be covered.	
	Learning Outcome: *The learner would be able to* • *Understand the concept of Entrepreneurship* • *State the myths, advantages and limitations of Entrepreneurship* • *Interpret and analyze market research data and customer analysis to make informed business decisions.* • *Discuss the steps in the process of Entrepreneurship*	
2	**Technological Innovation and Entrepreneurship**	4-5
	Learning Objectives: • *To enhance creative problem-solving skills and to examine the importance of innovation in business success.* • *To identify the types of Innovation* • *To gain knowledge for taking an idea to product development stage while protecting the idea with IPR.*	
	Content: Foundations of Creativity and Innovations, Creative thinking process, Types of Innovation: Incremental, Disruptive, and Radical, Innovation Process: from idea to execution; Protecting ideas - Patents and IPR. Exploring Technological Innovation through Case Studies.	
	Learning Outcome: *The learner would be able to* • *Use their understanding of the role Technological innovation plays in driving business success.* • *To formulate steps for taking an idea to product stage with necessary patents*	
3	**Ideation, Prototyping, Testing, Validation and Commercialisation**	5-6
	Learning Objectives: • *Experiment to test Minimum Viable Products (MVPs) and validate business ideas.* • *To formulate a Build-Measure-Learn feedback loop for continuous improvement.*	

	Contents: Identifying customer needs and problems to solve, Ideation, Concept Development, Design Thinking, Prototyping, Minimum Viable Product (MVP), Testing, and Iterations. Understanding the Market, customer feedback and refinement of business idea based on feedback. *Note:* A real life case study covering key elements of the module shall be covered.	
	Learning Outcome: *The learner would be able to* • *Select specific measures to design, test, and validate Minimum Viable Products (MVPs) to assess business ideas.* • *Interpret the learnings from the build-measure-learn feedback loop to facilitate continuous improvement and learning.*	
4	**Financial Resources**	3-4
	Learning Objectives: • *Describe the key concepts, and strategies related to fundraising for entrepreneurial ventures.* • *Compare various funding sources, including angel investors, venture capitalists, grants, and crowdfunding platforms.* • *Devise and create compelling investor pitches, develop financial projections.*	
	Contents: Funding new ventures – bootstrapping, crowd sourcing, Angel investors, VCs, debt financing, and due diligence; Raising fund during life-cycle of a new ventures. *Note:* A real life case study covering key elements of the module shall be covered.	
	Learning Outcome: *The learner would be able to* • *Recognize various fundraising strategies and techniques, enabling s to choose the most appropriate funding sources for their entrepreneurial ventures.* • *Sketch effective pitches and fundraising campaigns tailored to different types of investors and funding sources, ensuring successful capital-raising efforts.*	
5	**National Entrepreneurial Culture**	4-5
	Learning Objectives: • *To gain knowledge of legal and regulatory requirements for startups, including compliance with relevant regulations.* • *To identify the various government initiatives to develop the start-up ecosystem.*	
	Contents: Entrepreneurial Ecosystem in India, Key regulations and legal aspects, Forms of Business Ownership, MSMED Act 2006 and its implications, schemes and policies of the Ministry of MSME, role and responsibilities of various government organisations, departments,	

	banks etc. Government incentives for entrepreneurship, Incubation, & Acceleration.	
	Learning Outcome: *The learner would be able to* • *Describe the current scenario of Entrepreneurial activity in India.* • *To state legal and regulatory requirements and compliances for start-ups.* • *To state the various government initiatives to support the entrepreneurs.*	
6	**Start-up Case Studies**	3-4
	Learning Objectives*:* *To relate the real life case studies and analyse them for acquiring the clarity on various aspects of entrepreneurship covered in the first 5 modules*	
	Contents: Case Studies of various start-ups (with Indian Context): Start-ups from Tech, Edtech, Fintech, and Agriculture domain; Study of successful start-ups and failed start-ups.	
	Learning Outcome: • *To evaluate the real-world examples and case studies that will help them understand the practical aspects of idea to product, fundraising and financial management in the context of entrepreneurship.*	
7	***Course Conclusion***	1

In-semester Assessment - Continuous Assessment: Suggested

1 Teams of 3-4 students shall present a One-Minute business idea pitch– ideation phase-10 marks
2 Teams of 3-4 students shall present a Three-Minute Business Pitch –Validation phase-10 marks
3 Teams of 3-4 students shall present a Five-Minute Business Pitch for Funding- 15 marks
4 Teams of 3-4 students shall present analysis of one case study of successful or failed start-up- (15 Marks)

Course Outcome: Learner will be able to

CO1: State the concept of Entrepreneurship and Indian Start-up ecosystem
CO2: Identify the business ideas and to analyse the environment for potential business opportunity.
CO3: Identify the specific measures to design, test, and validate Minimum Viable Product.
CO4: State the key concepts, and strategies related to fundraising for entrepreneurial ventures.
CO4: Identify the legal and regulatory framework for entrepreneurs in Indian context.
CO5: Analyse and correlate the reasons for the success or the failure of entrepreneurial firms.

Text Books:

1. Poornima Charantimath, Entrepreneurship Development- Small Business Enterprise, Pearson
2. Education Robert D Hisrich, Michael P Peters, Dean A Shapherd, Entrepreneurship, The McGrawHill Company
3. Dr TN Chhabra, Entrepreneurship Development, Sun India Publications, New Delhi
4. Vasant Desai, Entrepreneurial Development and Management, Himalaya Publishing House
5. Maddhurima Lall, Shikah Sahai, Entrepreneurship, Excel Books

6. Rashmi Bansal, STAY hungry STAY foolish, CIIE, IIM Ahmedabad
7. Law and Practice relating to Micro, Small and Medium enterprises, Taxmann Publication Ltd.

Reference Books:

1. Zero to One: Notes on Startups, or How the Build the Future by Peter Thiel
2. The Lean Startup: How Today's Entrepreneurs Use Continuous Innovation to Create Radically Successful Businesses by Eric Ries
3. India as Global Start-up Hub: Mission with Passion by C B Rao
4. Innovation and Entrepreneurship: Practice and Principles by Peter F Drucker
5. Effective Entrepreneurial Management: Strategy, Planning, Risk Management, and Organization - Robert D. Hisrich, Veland Ramadani, Springer (2017)
6. Entrepreneurship- Theory, Process Practice –by Kuratko &Hodgetts, Thompson South-Western Publication

Relevant Websites:

1. www.msme.gov.in
2. www.dcmesme.gov.in
3. www.msmetraining.gov.in

Other Resources:

1. NPTEL Course: Entrepreneurship By Prof. C Bhaktavatsala Rao, IIT Madrao
   Weblink https://onlinecourses.nptel.ac.in/noc20_mg35/preview
2. NPTEL Course: Entrepreneurship Essentials By Prof. Manoj Kumar Mondal, IIT Kharagpur
   Weblink https://onlinecourses.nptel.ac.in/noc21_ge06/preview

Course Type	Course Code	Course Name	Credits
PCC	MEPCC611	MACHINE DESIGN	03

Examination Scheme					
Distribution of Marks			Exam Duration (Hrs.)		Total Marks
In-semester Assessment		End Semester Exam (ESE)			
Continuous Assessment	Mid-Semester Exam (MSE)		MSE	ESE	
20	30	50	1.5	2	100

Pre-requisite :

1. ESE 101 Engineering Mechanics
2. MEPCC302 Mechanics of Solid
3. MEPCC303 Material Science and Engineering
4. MEPCC406 Theory of Machine
5. MEPCC408 Manufacturing Technology

Program Outcomes addressed:

1. PO1: Engineering knowledge
2. PO2: Problem analysis
3. PO3: Design/development of solutions
4. PO4: Conduct investigations of complex problems
5. PO6: The Engineer and the World
6. PO8: Individual and Collaborative Team work
7. PO9: Communication
8. PO10: Project Management and Finance

Course Objectives:

1. Familiarize students with the basic principles of machine design and with various design considerations.
2. Acquaint students with functional and strength design principles of important machine elements.
3. Guide students through the design calculation, preparation of working drawings based on designs.
4. Familiarize students to the use of design data books & various codes of practice for the design/selection of standard machine elements.

Module	Details	Hrs
	Course Introduction Machine Design equips students with the principles, methods, and tools essential for designing mechanical systems. It bridges theory and practice,	**01**

	fostering innovation and performance improvement. Students gain a solid foundation in stress analysis, material selection, and failure criteria—key concepts vital for real-world applications	
01.	**Design Fundamentals** ***Learning Objective/s:*** *To understand the fundamental principles of machine design*	**5-7**
	Contents:	
	Design methods, Basic principle of Machine Design, Aesthetic and Ergonomics consideration in design, Material properties and their uses in design, Modes of failures, Factor of safety, Design stresses, Theories of failures, Standards, Preferred Series and Numbers. Variables stresses, reversed, repeated, fluctuating stresses	
	Self-Learning Topics: ***Learning Outcomes :*** *A learner will be able to* *LO 1.1: Select the factor of safety and design stresses for the component design (P.I.- 1.3.1, 2.4.1)* *LO 1.2: Identify the modes of failure. (P.I.- 1.3.1, 2.1.3, 2.4.1)* *LO 1.3: Use the theory of failure as per requirement. (P.I.- 1.2.1, 2.4.4)* *LO 1.4: Use the Standards, I.S. Codes, Preferred Series and Numbers (P.I.- 1.3.1, 2.4.4)* *LO 1.5: Differentiate the reversed, repeated and fluctuating stresses. (P.I.- 1.3.1, 2.1.2)*	
02.	**Basics Principles of Design** ***Learning Objective/s:*** *Design components under different loading conditions using stress analysis, fatigue concepts, and failure criteria.*	**5-7**
	Contents: Design for tensile, compressive, shear, bending and torsional loads. Static and fatigue stress concentration factors, Methods of stress concentrations, Endurance limit - estimation of endurance limit, Soderberg and Goodman criteria	
	Self-Learning Topics:	
	Learning Outcomes : *A learner will be able to* *LO 2.1: Identify and determine the resisting area for different failure in components. (P.I.-1.4.1, 2.4.1)* *LO 2.2: Use the static and fatigue stress concentration factors and SN Curve for design. (P.I.- 2.1.2, 2.3.1)* *LO 2.3: Estimate the endurance limit. (P.I.- 1.3.1, 2.4.1)*	

	LO 2.4: Apply the Soderberg and Goodman design criteria for the components design. (P.I.- 2.1.3, 2.4.1)	
03.	**Design against static loads:** ***Learning Objective/s:*** *Design the machine elements like knuckle joints, eccentrically loaded bolted joints, power screws, and helical springs subjected to static load conditions for the given specification.* **Contents:** Knuckle joint, Bolted joints under eccentric loading; Power Screw- Screw Jack. Helical Coil Springs under static load. ***Self-Learning Topics:*** *Socket and Spigot Cotter joint, Leaf Spring.* ***Learning Outcomes :*** *A learner will be able to* *LO 3.1: Design knuckle joints for given specification, (P.I. -2.4.1, 3.1.6)* *LO 3.2: Check the fork, eye and pin for different mode of failure by identifying the correct resisting area. (P.I.- 1.4.1, 2.2.1, 2.4.1,3.2.3)* *LO 3.3: Select the standard bolt from the catalogue for the Eccentric load in the plane of the bolts. (P.I-. 2.3.1, 3.1.4)* *LO 3.4: Design a screw Jack for given specification. (P.I.- 1.4.1,2.4.1, 3.1.6)* *LO 3.5: Design a helical spring for the given specification under static loads. (P.I.- 1.3.1, 2.1.3, 3.1.6)*	**9-11**
04.	**Design of Power transmitting elements:** ***Learning Objective/s:*** *Design the shafts, keys and couplings considering load conditions, fatigue criteria, and functional requirements for given specifications.* **Contents:** Shafts: Design under static and fatigue criteria. Keys: Types of keys and their selection based on shafting condition. Couplings: Classification of couplings. Design of flange couplings, bush pin flexible coupling. ***Self-Learning Topics:*** ***Learning Outcomes :*** *A learner will be able to* *LO 4.1: Design a power transmitting shaft subjected to static and fatigue criteria (P.I.-1.3.1, 2.1.2, 2.3.1, 3.1.6, 4.3.1)* *LO 4.2: Select key for the given shaft and check for the shear and crushing failure (P.I. - 1.3.1,2.1.2, 2.3.1, 3.1.4,3.1.6)* *LO 4.3: Design a coupling and checking various coupling elements under different failure criteria. (P.I.- 2.1.2, 2.3.1, 2.4.4,3.3.1, 4.3.1)*	**9-11**
	Selection of Rolling Element Bearings:	

05.	***Learning Objective/s:*** *Select the suitable rolling contact bearing based on constant and variable loads and speed.*	**5-7**
	Contents: Types of bearing and designation, selection of rolling contact bearings based on constant / variable load & speed conditions.	
	Self-Learning Topics:	
	Learning Outcomes : *A learner will be able to* *LO 5.1: Know the function and components and the terminology of the rolling contact bearing. (P.I.-1.3.1. P.I.-1.4.1)* *LO 5.2: Determine the rated life of the bearing for required reliability. (P.I.-2.1.2, P.I.-2.4.1, PI 4.3.1)* *LO 5.3: Select the suitable rolling contact bearing based on given specifications (P.I.-3.1.4, PI 3.1.6, PI 4.3.2)*	
06.	**Design for Manufacturing and Assembly** ***Learning Objectives:*** *Understand the importance of DFM and DFA in product development, distinguish them from traditional design approaches, and apply design considerations for casting, forging, and machining*	**4-6**
	Contents: Importance of DFM and DFA in product development, Differences between traditional design and DFM/DFA approaches, Benefits of integrating DFM and DFA in design, Design consideration for Casting, Forging and Machining.	
	Self-Learning Topics:	
	Learning Outcomes : *A learner will be able to* *LO 6.1: Differentiate between traditional design and DFMA approach. (P.I.-1.3.1,2.1.3)* *LO 6.2: State the various DFMA consideration in design. (P.I.-1.2.1, 1.4.1)* *LO 6.3: Analyze the benefits of integrating DFM and DFA in the design process. (P.I.-1.3.1, 2.2.3)* *LO 6.4: Apply design considerations for casting, forging, and machining in product development. (P.I.-1.4.1, 2.2.2, 6.2.1)* *LO 6.5: A Task-Based Group Activity on DFM and DFA Applications (PI 6.1.1, PI 6.3.1 PI-8.2.1, PI 8.2.2, PI 9.1.1, PI 9.1.2, PI 9.2.2, PI 10.1.1, 10.3.1)* *Each group (max 4 students) will participate in a Manufacturing-Oriented Redesign Task with the following deliverables:* *A. Product Selection: Choose an existing mechanical component (e.g., engine bracket, gearbox casing, or machine tool holder) currently produced using conventional design methods.*	

	B. Design Evaluation: Analyze the product's manufacturing and assembly process using criteria like complexity, material usage, tolerances, and cost. Identify drawbacks in manufacturability or assembly. *C. Redesign Phase: Apply DFM and DFA principles to improve design for one of the following processes: casting, forging, or machining. Propose simplifications, process optimizations, and part consolidation. Emphasize cost reduction and manufacturability.* *D. Planning and Presentation: Prepare a concise report (max 5 pages) and a visual presentation that includes:* *Redesign rationale* *Before-after comparison (features, cost, assembly steps)* *A Gantt chart or task plan outlining team contributions* *Justification based on manufacturability, cost, and efficiency*	
	Course Conclusion	**01**
	Total	**45**

Performance Indicators:

P.I. No.	**P.I. Statement**
1.2.1	Apply laws of natural science to an engineering problem
1.3.1	Apply fundamental engineering concepts to solve engineering problems
1.4.1	Apply Mechanical engineering concepts to solve engineering problems.
2.1.2	Articulate problem statements and identify objectives
2.1.3	Identify the mathematical, engineering and other relevant knowledge that applies to a given problem
2.2.1	Reframe complex problems into interconnected sub-problems
2.2.2	Identify, assemble and evaluate information and resources.
2.2.3	Identify existing processes/solution methods for solving the problem, including forming justified approximations and assumptions
2.3.1	Combine scientific principles and engineering concepts to formulate model/s (mathematical or otherwise) of a system or process that is appropriate in terms of applicability and required accuracy.
2.4.1	Apply engineering mathematics and computations to solve mathematical models
2.4.4	Extract desired understanding and conclusions consistent with objectives and limitations of the analysis.
3.1.4	Extract engineering requirements from relevant engineering Codes and Standards such as ASME, ASTM, BIS, ISO and ASHR
3.1.6	Determine design objectives, functional requirements and arrive at specifications
3.2.3	Identify suitable criteria for the evaluation of alternate design solutions

3.3.1	Apply formal decision-making tools to select optimal engineering design solutions for further development.
4.3.1	Use appropriate procedures, tools, and techniques to conduct experiments and collect data.
4.3.2	Analyze data for trends and correlations, stating possible errors and limitations.
6.2.1	Interpret legislation, regulations, codes, and standards relevant to your discipline and explain its contribution to the protection of the public.
6.3.1	Identify risks/impacts in the life-cycle of an engineering product or activity
8.2.1	Demonstrate effective communication, problem-solving, conflict resolution and leadership skills
8.2.2	Treat other team members respectfully
9.1.1	Read, understand and interpret technical and non-technical information
9.1.2	Produce clear, well-constructed, and well-supported written engineering documents
10.1.1	Describe various economic and financial costs/benefits of an engineering activity
10.3.1	Identify the tasks required to complete an engineering activity, and the resources required to complete the tasks.

Course Outcomes: A learner will be able to -

1. To demonstrate the understanding of various design consideration. *(LO 1.1, LO 1.2, LO 1.3, LO 1.4, LO 1.5)*
2. To design machine elements under various conditions by selecting suitable materials, design stresses on the basis of strength concept. (*LO 2.1, LO 2.2, LO 2.3, LO 2.4, LO 3.1, LO 3.2, LO 3.3, LO 3.4, LO 3.5)*
3. To design power transmitting machine elements subjected to static and fluctuating loads. (*LO 4.1, LO 4.2, LO 4.3, LO 5.1, LO 5.2, LO 5.3*)
4. To select bearings for a given application from the manufacturers catalogue. *LO 5.4, LO 5.5)*
5. Apply DFMA principles to various design processes *(LO 6.1, LO 6.2, LO 6.3, LO 6.4, LO 6.5)*

CO-PO Mapping Table with Correlation Level

CO ID	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MEPCC601.1	3	3	--	--	--	--	--	--	--	--	--
MEPCC601.2	3	3	3	--	--	--	--	--	--	--	--
MEPCC601.3	3	3	3	3	--	--	--	--	--	--	--
MEPCC601.4	3	3	3	3	--	--	--	--	--	--	--
MEPCC601.5	3	3	3	3	--	3	--	3	3	3	--
Average	**3**	**3**	**3**	**3**	**--**	**3**	**--**	**3**	**3**	**3**	--

NOTE: CO can be mapped to PO at level 3 if at least two PIs are associated with that CO; otherwise, it can be mapped at level 2.

Text Books :

1. Design of Machine Elements - V.B. Bhandari, Second edition, 2007, Tata McGraw Hill Publication
2. Design of Machine Elements – C.S. Sharma and Kamlesh Purohit. 2009, Prentice Hall India Publication
3. Machine Design by N. C. Pandya and C. S. Shah, 2006, Charotar Publishing House Pvt. Limited.
4. Machine Design by R. S. Khurmi and J.K. Gupta, 2007, S. Chand and company Ltd.

Reference Books :

1. Machine Design -An Integrated Approach - Robert L. Norton, Second edition, 2006, Pearson Education
2. Mechanical Engineering Design by Joseph Edward Shigley, Charles R. Mischke and Richard Gordon Budynas, 2004, McGraw Hill Publication
3. Design Data: Data Book of Engineers by PSG College,2020, Kalaikathir, Achchagam-Coimbatore

Other Resources :

1. https://nptel.ac.in/courses/112/105/112105124/ - Design of Machine Elements, IIT Kharagpur
2. https://nptel.ac.in/courses/112/106/112106137/ - Machine Design-II, IIT Madras

IN-SEMESTER ASSESSMENT (50 MARKS)

1. Continuous Assessment (20 Marks)

Suggested breakup of distribution

Assignments on live problems/ case studies	:	10 Marks
Open book test/ Open notes test	:	05 Marks
Regularity and active participation	:	05 Marks

2. Mid Semester Exam (30 Marks)

Mid semester examination will be based on 40% to 50% syllabus.

END SEMESTER EXAMINATION (50 MARKS)

End Semester Examination will be based on syllabus coverage up to the Mid Semester Examination carrying 20% weightage, and the syllabus covered from MSE to ESE carrying 80% weightage.

Course Type	Course Code	Course Name	Credits
PEC	MEPEC6021	REFRIGERATION AND AIR CONDITIONING	03

Examination Scheme					
Distribution of Marks			Exam Duration (Hrs.)		Total Marks
In-semester Assessment		End Semester Examination (ESE)			
Continuous Assessment	Mid-Semester Exam (MSE)		MSE	ESE	
20	30	50	1.5	2	100

Pre-requisite:

1. MEPCC304: Thermodynamics
2. MEPCC407: Thermal Engineering

Program Outcomes addressed:

1. PO1: Engineering knowledge
2. PO2: Problem analysis
3. PO3: Design/Development of Solutions
4. PO6: The Engineer and the World
5. PO9: Communication

Course Objectives:

1. To impart a basic understanding of principles of Heat Pump, refrigeration and air conditioning.
2. To study various conventional and non-conventional refrigeration cycles and evaluate the performance of each cycle.
3. To understand the construction and working of different controls of refrigeration and air-conditioning systems with their applications.

Module	Details	Hrs.
	Course Introduction This course offers a basic understanding of Refrigeration and Air Conditioning. Different refrigeration cycles and a grasp of psychrometry and psychrometric processes utilized for air conditioning are also covered. Additionally, it contains cooling load estimation and various controls as well as their applications.	**01**
01.	**Introduction to Refrigeration and Refrigerants** ***Learning Objectives:*** *1. To impart the knowledge of engineering fundamentals in basic working principles of refrigerator and heat pump.* *2. To get acquaint with designation of the refrigerants and selection of an appropriate refrigerant as per the application.*	**3-5**

	Contents: 1.1 Introduction to Refrigeration: Carnot refrigerator, Carnot heat pump, unit of refrigeration, Co-efficient of Performance 1.2 Refrigerants: Desirable properties of refrigerants, ASHRAE numbering system for refrigerants. Thermodynamic, Chemical and Physical properties, Secondary refrigerants, ODP and GWP, Montreal protocol and India's commitment, Recent substitutes for refrigerants	
	Self-Learning Topics: *Carnot refrigerator, Carnot heat pump*	
	Learning Outcomes: *A learner will be able to* *LO 1.1: Define Refrigeration, Ton of Refrigeration and Coefficient of Performance. (PI:1.2.1)* *LO 1.2: Calculate the Coefficient of Performance (COP) of Carnot refrigerator and heat pump. (PI:1.4.1)* *LO 1.3: Apply the ASHRAE designation system to designate a refrigerant using chemical formula. (PI:1.4.1)* *LO 1.4: Compare different refrigerants based on their thermodynamic, chemical, and physical properties and select the appropriate one as per the application. (PI: 2.2.4)* *LO 1.5: Identify the environmental impact of refrigerants considering protocols by understanding Ozone Depletion Potential (ODP) and Global Warming Potential (GWP). (PI:2.2.2, 6.2.1, 6.3.2, 9.3.1)* *LO 1.6: Recommend alternative refrigerants base*d on their environmental impact *and sustainability in modern refrigeration systems. (PI:2.2.2, 6.3.1, 9.3.2)*	
02.	**Vapour Compression Refrigeration, Vapour Absorption Refrigeration and Heat Pump** ***Learning Objective:*** *To get familiarized with the various refrigeration systems and heat pump for analyzing their coefficient of performance.*	**6-8**
	2.1 Vapour Compression Refrigeration System: Simple vapour compression cycle, Effect of liquid sub cooling & superheating, effect of evaporator and condenser pressures, methods of subcooling, use of P-h charts, Actual VCR cycle, Use of P-h Charts, Comparison between air-cooled and water-cooled condenser based air conditioning systems, Types of condensers, evaporators, expansion devices and Compressors. 2.2 Heat Pump: Performance, Primary energy ratio, Energy efficiency, Coefficient of ratio.	
	Self-Learning Topics: *Heat pump*	
	Learning Outcomes: *A learner will be able to*	

	LO 2.1: Utilize P-h charts to analyze vapour compression refrigeration cycles considering the effect of the effects of liquid subcooling, superheating, evaporator, and condenser pressures (PI: 2.4.1) *LO 2.2: Classify and choose different types of Heat pumps, condensers, evaporators, expansion devices, and compressors based on applications. (PI: 2.2.4)* *LO 2.3: Define Performance factor, Energy Efficiency Ratio for heat pump. (PI:1.2.1)* *LO 2.4: Calculate the COP of vapour compression heat pump. (PI: 1.4.1)*	
03.	**Other and Non-Conventional Refrigeration Systems** ***Learning Objective/s:*** *Analyze the various refrigeration systems including non-conventional to determine their coefficient of performance.*	**6-8**
	Contents: 3.1 Other Refrigeration Systems: Vapour Absorption Refrigeration, Importance of VAR system, COP of ideal VAR system, Ammonia-water VAR system, Lithium Bromide – Water VAR system (Single and double effect), Electrolux refrigeration system. 3.2 Non-Conventional Refrigeration Systems: Thermoelectric Refrigeration, Thermo-acoustic Refrigeration, Vortex Tube Refrigeration.	
	Learning Outcomes: *A learner will be able to* *LO 3.1: Analyze the Coefficient of Performance (COP) for an ideal VAR system using established thermodynamic relationships. (PI: 2.1.2, 2.4.1)* *LO 3.2: Evaluate the working principle of thermoelectric, thermoacoustic and vortex tube refrigeration and discuss their potential applications. (PI: 6.3.1, 6.3.2)*	
04.	**Human Comfort and Psychrometry** ***Learning Objective/s:*** *To apply basic concepts psychrometry to analyze different human comfort conditions.*	**6-8**
	Contents: 4.1 Human Comfort: Thermal exchange of body with environment, Effective temperature, Comfort chart, Comfort zone, Indoor Air Quality, Green Buildings 4.2 Psychrometry: Need for air conditioning, Principle of psychromerty, Psychrometric properties, chart and processes, air washers, requirements of comfort air conditioning, Adiabatic air mixing, Psychrometric chart, RSHF, GSHF, ERSHF, Bypass factor process, Numerical based on psychrometric chart and Apparatus dew point .	

	***Learning Outcomes**:* *A learner will be able to* *LO 4.1: Define effective temperature, interpret comfort charts, and delineate comfort zones for indoor environments. (PI: 1.2.1, 9.1.1, 9.3.2)* *LO 4.2: Evaluate green building concepts and their role in enhancing human comfort. (PI: 2.2.2, 6.3.2)* *LO 4.3: Identify various psychrometric processes, properties using psychometric charts. (PI: 2.2.3)* *LO 4.4: Calculate sensible heat factor and bypass factor for a given process. (PI: 1.4.1)* *LO 4.5: Analyze air conditioning parameters as per the application. (PI:2.4.1, 6.3.1)*	
05.	**Design of Air Conditioning Systems** ***Learning Objectives:*** *To analyze the cooling load for various air conditioning systems.* **Contents:** Different Heat sources, Adiabatic mixing of two air streams, Bypass factor, sensible heat factor, RSHF, GSHF, ERSHF, Room apparatus dew point and coil apparatus dew point, Ventilation and infiltration, Inside and Outside Design condition, Cooling Load estimation, Introduction to Unitary Products viz; Room/Split and Packaged Air Conditioners, Introduction to recent developments viz. Variable Refrigerant Flow systems, VAV control systems, Inverter Units.. ***Self-Learning Topics:*** *Summer and winter air conditioning.* ***Learning Outcomes:*** *A learner will be able to* *LO:5.1: Define Air Conditioning. (PI:1.2.1)* *LO 5.2: Identify the required information about heat sources and cooling load required. (PI:* 2.2.2*)* *LO 5.3: Calculate the sensible and latent heat load for given application. (PI:1.4.1)* *LO 5.4: Extract the required parameters for cooling load estimation from ASHRAE handbook. (PI 3.1.4)* *LO 5.5: Apply different load estimation techniques to analyze the cooling requirements of a building. (PI:* 2.4.1, 6.3.1*)* *LO 5.6: Integrate survey data and economic considerations into the design process of an air conditioning system. (PI: 3.1.6, 6.2.1)*	**9-11**
06.	**Air Distribution System** ***Learning Objective/s:*** *To select a suitable duct system and air handling system for a given application.* **Contents:** 6.1 Duct Design: Friction chart for circular ducts, Equivalent diameter of a circular duct for rectangular ducts, Static pressure regain and equal pressure drop methods of duct design, Factors considered in air distribution system, Air distribution systems for cooling and heating.	**8-10**

	6.2 Controls: LP/HP cutoff, Thermostats, Humidistats, Interlocking control, Electronic Controllers. 6.3 Applications: Refrigeration & A/C Ice plant: food storage plants – diary and food processing plants, Food preservation, Freeze Drying, A/c in textile, printing pharmaceutical industry and Hospitals, Liquefaction of LNG, Liquefaction of gases (cryogenics), Deep sea water air-conditioning	
	Self-Learning Topics: *Various pressure losses in ducts*	
	Learning Outcomes: *A learner will be able to* *LO 6.1: Define duct and air handling unit. (PI: 1.2.1)* *LO 6.2: Calculate pressure losses, airflow through ducts, for determination of equivalent diameters. (PI:1.4.1)* *LO 6.3: Apply design methodologies for duct systems to analyze air flow to minimize pressure losses. (PI:2.4.1, 6.3.4)* *LO 6.4: Identify and choose appropriate components such as filters, supply and return grills, controls and sensors as per application and significance of supplementary (PI: 2.1.2, 6.3.1)*	
	Course Conclusion At the end of the course, students would be expected to be able to 1. Demonstrate the working principle of refrigerators and heat pumps. 2. Determine COP of various Refrigeration systems. 3. Use psychrometric processes to get the required comfort conditions 4. Conduct a heat load analysis to calculate the cooling load for a given application and select an appropriate air distribution system. Understand the working principle of different controls and their applications.	**01**
	Total	**45**

Performance Indicators:

PI No.	**PI Statement**
1.2.1	Apply laws of natural science to an engineering problem.
1.4.1	Apply mechanical engineering concepts to solve engineering problems.
2.1.2	Identify engineering systems, variables, and parameters to solve the problems.
2.2.2	Identify, assemble, and evaluate information and resources.
2.2.3	Identify existing processes/solution methods for solving the problem, including forming justified approximations and assumptions.
2.2.4	Compare and contrast alternative solution processes to select the best process.
2.4.1	Apply engineering mathematics and computations to solve mathematical models.
3.1.4	Extract engineering requirements from relevant engineering Codes and Standards.
3.1.6	Determine design objectives, functional requirements, and arrive at specifications.

6.2.1 Interpret legislation, regulations, codes, and standards relevant to your discipline and explain its contribution to the protection of the public.

6.3.1 Identify risks/impacts in the life cycle of an engineering product or activity.

6.3.2 Understand the relationship between the technical, socio-economic, and environmental dimensions of sustainability.

6.3.4 Apply principles of preventive engineering and sustainable development to an engineering activity or product relevant to the discipline

9.1.1 Read, understand, and interpret technical and non-technical information.

9.3.1 Create engineering-standard figures, reports, and drawings to complement writing and presentations.

9.3.2 Use a variety of media effectively to convey a message in a document or a presentation.

Course Outcomes: A learner will be able to -

1 Demonstrate an understanding of refrigerants designation and ODP, GWP, regulations and Protocols. *(LO 1.3, LO 1.4, LO 1.5, LO 1.6)*

2 Analyse Vapour Compression Refrigeration Systems and heat pump. (*LO1.1, LO 1.2, LO 2.1, LO 2.3, LO 2.4)*

3 Analyze Vapour absorption system and Evaluate the working principal of Non-Conventional Refrigeration Systems. (*LO 3.1, LO 3.2)*

4 Interpret psychometric information and perform numerical analysis as per the comfort conditions required.(*LO 4.1, LO 4.2, LO 4.3 , LO 4.4, LO 4.5)*

5 Conduct a comprehensive cooling load analysis to design an air conditioning systems integrating building survey and component selection. (*LO 2.2, LO 5.1, LO 5.2, LO 5.3, LO 5.4, LO 5.5, LO 5.6)*

6 Design a sustainable air distribution system and select appropriate control systems as per their industrial applications considering the risk /impact on the life cycle of the system (*LO 6.1, LO 6.2, LO 6.3, LO 6.4)*

CO-PO Mapping Table with Correlation Level

CO ID	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MEPEC6021.1	2	3	--	--	--	3	--	--	3	--	--
MEPEC6021.2	3	2	--	--	--	--	--	--	--	--	--
MEPEC6021.3	--	3	--	--	--	3	--	--	--	--	--
MEPEC6021.4	3	3	--	--	--	3	--	--	3	--	--
MEPEC6021.5	3	3	3	--	--	3	--	--	--	--	--

MEPEC6021.6	3	3	--	--	--	3	--	--	--	--	--
Average	**3**	**3**	**3**	**--**	**--**	**3**	**--**	**--**	**3**	**--**	**--**

NOTE: CO can be mapped to PO at level 3 if at least two PIs are associated with that CO; otherwise, it can be mapped at level 2.

Text Books:

1. Refrigeration and air-conditioning – C P Arora, TMH
2. Refrigeration and Air-conditioning – R. K. Rajput
3. Refrigeration and air-conditioning – W F Stoeker and J W Jones, TMH
4. Modern Air-conditioning practice – C P Arora, TMH
5. Basic Refrigeration and air-conditioning- P. Ananthanarayana, TMH

Reference Books:

1. Principles of refrigeration – R J Dossat, Willey Eastern Publication
2. Introduction to Refrigeration and Air-Conditioning Systems - Allen T. Kirpatrick
3. ASHRAE Handbook of Systems
4. ASHRAE Handbook of Equipments
5. ISHRAE Air Conditioning Handbook

Other Resources:

1. NPTEL Course: Refrigeration and Air Conditioning by Prof. M. Ramgopal
   Prof. R.C. Arora, Department of Mechanical Engineering at IIT Kharagpur :-Web link- NPTEL :: Mechanical Engineering - Refrigeration and Air Conditioning
2. NPTEL Course: Refrigeration and Air Conditioning by Prof. Ravi Kumar
   Prof. R.C. Arora, Department of Mechanical Engineering at IIT Roorkee :-Web link- NPTEL :: Mechanical Engineering - NOC:Refrigeration and air-conditioning

IN-SEMESTER ASSESSMENT (50 MARKS)

1. Continuous Assessment – Theory (20 Marks)

Suggested breakup of distribution

One MCQ test as per GATE exam pattern/ level	:	05 Marks
One Class test	:	05 Marks
Flip classroom	:	05 Marks
Regularity and active participation	:	05 Marks

2. Mid Semester Exam (30 Marks)

Mid semester examination will be based on 40% to 50% syllabus.

END SEMESTER EXAMINATION (50 MARKS)

End Semester Examination will be based on syllabus coverage up to the Mid Semester Examination (MSE) carrying 20%-30% weightage, and the syllabus covered from MSE to ESE carrying 70%-80% weightage.

Course Type	Course Code	Course Name	Credits
PEC	MEPEC6022	HEATING, VENTILATION AND AIR CONDITIONING	03

Examination Scheme					
Distribution of Marks			Exam Duration (Hrs.)		Total Marks
In-semester Assessment		End Semester Examination (ESE)			
Continuous Assessment	Mid-Semester Exam (MSE)		MSE	ESE	
20	30	50	1.5	2	100

Pre-requisite:

1. MEPCC304: Thermodynamics
2. MEPCC407: Thermal Engineering

Program Outcomes addressed:

1. PO1: Engineering knowledge
2. PO2: Problem analysis
3. PO3: Design/Development of Solutions
4. PO6: The Engineer and the World
5. PO9: Communication

Course Objectives:

1. To impart the basic understanding of fundamental principles of refrigeration and air conditioning and evaluate the environmental impact of different refrigerants and explore eco-friendly alternatives.
2. To recognise different components of refrigeration and air conditioning systems and their functions.
3. To utilize psychometric chart for air property analysis and perform cooling load calculations for designing HVAC systems following industry standards.

Module	Details	Hrs.
	Course Introduction This course provides a foundational understanding of Heating, Ventilation, Air Conditioning, and Refrigeration (HVAC&R) systems, integrating modern advancements in energy efficiency and sustainable practices. Emphasizing recent trends, it covers the latest refrigeration cycles, eco-friendly refrigerants, and smart HVAC controls which can be integrated with IoT and AI. The course also explores psychrometry for human comfort, cooling load estimation, and energy-efficient air distribution systems. With a focus on green building concepts and evolving global environmental protocols, students will gain insights into designing sustainable and high-performance HVAC&R systems.	**01**
01.	**Introduction to Refrigeration and Refrigerants** ***Learning Objectives:*** *1. To impart the knowledge of engineering fundamentals in basic working principles of refrigerator and heat pump.*	**3-5**

	2. To get acquaint with designation of the refrigerants and selection of an appropriate refrigerant as per the application.	
	Contents: 1.1 Introduction to Refrigeration: Carnot refrigerator, Carnot heat pump, unit of refrigeration, Co-efficient of Performance 1.2 Refrigerants: Desirable properties of refrigerants, ASHRAE numbering system for refrigerants. Thermodynamic, Chemical and Physical properties, Secondary refrigerants, ODP and GWP, Montreal protocol and India's commitment, Recent substitutes for refrigerants	
	Self-Learning Topics: *Carnot refrigerator, Carnot heat pump*	
	Learning Outcomes: *A learner will be able to* *LO 1.1: Define Refrigeration, Ton of Refrigeration and Coefficient of Performance. (PI:1.2.1)* *LO 1.2: Calculate the Coefficient of Performance (COP) of Carnot refrigerator and heat pump. (PI:1.4.1)* *LO 1.3: Apply the ASHRAE designation system to designate a refrigerant using chemical formula. (PI:1.4.1)* *LO 1.4: Compare different refrigerants based on their thermodynamic, chemical, and physical properties and select the appropriate one as per the application. (PI: 2.2.4)* *LO 1.5: Identify the environmental impact of refrigerants considering protocols by understanding Ozone Depletion Potential (ODP) and Global Warming Potential (GWP). (PI:2.2.2, 6.2.1, 6.3.2, 9.3.1)* *LO 1.6: Recommend alternative refrigerants based on their environmental impact and sustainability in modern refrigeration systems. (PI:2.2.2, 6.3.1, 9.3.2)*	
02.	**Vapour Compression Refrigeration, Vapour Absorption Refrigeration and Heat Pump**	**8-10**
	Learning Objective: *To get familiarized with the various refrigeration systems for analyzing their coefficient of performance.*	
	Contents: 2.1 Vapour Compression Refrigeration System: Simple vapour compression cycle, Effect of liquid sub cooling & superheating, effect of evaporator and condenser pressures, methods of subcooling, use of P-h charts, Actual VCR cycle, Use of P-h Charts, Comparison between air-cooled and water-cooled condenser-based air conditioning systems, Types of condensers, evaporators, expansion devices and Compressors. 2.2 Vapour Absorption Refrigeration System: Simple and practical vapour absorption system, Refrigerant-	

	adsorbent properties, COP of ideal vapour absorption system, Domestic Electrolux refrigerator, Lithium bromide absorption system 2.3 Heat Pump: Performance, Primary energy ratio, Energy efficiency, Coefficient of ratio. Heating season performance factor, Seasonal energy efficiency ratio, Classification of heat pump, Vapour compression heat pump systems. Heat pump application in an industry	
	Self-Learning Topics: *Heat pump applications in an industry*	
	Learning Outcomes: *A learner will be able to* *LO 2.1: Utilize P-h charts to analyze vapour compression refrigeration cycles considering the effect of the effects of liquid subcooling, superheating, evaporator, and condenser pressures (PI: 2.4.1)* *LO 2.2: Classify and choose different types of Heat pumps, condensers, evaporators, expansion devices, and compressors based on applications. (PI: 2.2.4)* *LO 2.3: Analyze the COP of vapour absorption system. (PI: 2.4.1)* *LO 2.4: Define Performance factor, Energy Efficiency Ratio for heat pump. (PI:1.2.1)* *LO 2.5: Calculate the COP of vapour compression heat pump. (PI: 1.4.1)*	
03.	**Human Comfort and Psychrometry**	**7-9**
	Learning Objective/s: *To know the psychrometric processes for determining different human comfort conditions.*	
	Contents: 3.1 Human Comfort: Thermal exchange of body with environment, Effective temperature, Comfort chart, Comfort zone, Indoor Air Quality, Green Buildings 3.2 Psychrometry: Need for air conditioning, Principle of psychromerty, Psychrometric properties, chart and processes, air washers, requirements of comfort air conditioning, Adiabatic air mixing, Psychrometric chart, RSHF, GSHF, ERSHF, Bypass factor, Numerical based on psychrometric chart and Apparatus dew point .	
	Learning Outcomes*:* *A learner will be able to* *LO 3.1: Define effective temperature, interpret comfort charts, and delineate comfort zones for indoor environments. (PI: 1.2.1, 9.1.1, 9.3.2)* *LO 3.2: Evaluate green building concepts and their role in enhancing human comfort. (PI: 2.2.2, 6.3.2)* *LO 3.3: Identify various psychrometric processes, properties using psychometric charts. (PI: 2.2.3)*	

	LO 3.4: Calculate sensible heat factor and bypass factor for a given process. (PI: 1.4.1) *LO 3.5: Analyze air conditioning parameters as per the application. (PI:2.4.1, 6.3.1)*	
04.	**Cooling Load Calculations** ***Learning Objective:*** *To get acquaint with various air conditioning systems for determining the cooling load.* **Contents:** 4.1 Introduction to air conditioning: Classification of air conditioning system, relations summer and Winter Air conditioning 4.2 Cooling Load Estimation: Introduction, Components of cooling load, Different heat sources, Various load Estimation, Design of air conditioning system, building survey and economic aspect used in design. ***Self-Learning Topics:*** *Summer and winter air conditioning.* ***Learning Outcomes:*** *A learner will be able to* *LO:4.1: Define Air Conditioning. (PI:1.2.1)* *LO 4.2: Identify the required information about heat sources and cooling load required. (PI:* 2.2.2*)* *LO 4.3: Calculate the sensible and latent heat load for given application. (PI:1.4.1)* *LO 4.4: Extract the required parameters for cooling load estimation from ASHRAE handbook. (PI 3.1.4)* *LO 4.5: Apply different load estimation techniques to analyze the cooling requirements of a building. (PI:* 2.4.1, 6.3.1*)* *LO 4.6: Integrate building survey data and economic considerations into the design process of an air conditioning system. (PI: 3.1.6, 6.2.1)*	**7-9**
05.	**Air Distribution System** ***Learning Objective/s:*** *To select a suitable duct system and air handling system for a given application.* **Contents:** 5.1 Duct: Classification of ducts, duct material, pressure in ducts, Flow through duct, pressure losses in duct, Air flow through simple duct system, Equivalent diameter, Methods of duct system design 5.2 Air Handling Unit: Fan coil unit, Types of fans used air conditioning Introduction applications, Fan laws ,Filters, supply and return grills, Sensors. ***Self-Learning Topics:***	**6-8**

	Various pressure losses in ducts	
	Learning Outcomes: *A learner will be able to* *LO 5.1: Define duct and air handling unit. (PI: 1.2.1)* *LO 5.2: Calculate pressure losses, airflow through ducts, for determination of equivalent diameters. (PI:1.4.1)* *LO 5.3: Apply design methodologies for duct systems to analyze air flow to minimize pressure losses. (PI:2.4.1, 6.3.4)* *LO 5.4: Identify and choose appropriate components such as filters, supply and return grills, and sensors as per function and significance of supplementary (PI: 2.1.2, 6.3.1)*	
06.	**Controls and applications**	**7-9**
	Learning Objective/s: *To get familiarized with the working principle and applications of different controls.*	
	Contents: 6.1 Controls: LP/HP cutoff, Thermostats, Humidistats, Interlocking control, Electronic Controllers 6.2 Applications: Refrigeration & A/C Ice plant – food storage plants – diary and food processing plants, Food preservation, Freeze Drying, A/c in textile, printing pharmaceutical industry and Hospitals, Liquefaction of LNG, Liquefaction of gases (cryogenics), Deep sea water air-conditioning.	
	Self-Learning Topics: *Liquefaction of LNG, Liquefaction of gases (cryogenics)*	
	Learning Outcomes: *A learner will be able to* *LO 6.1: Identify the requirements of A/C system for different applications. (PI: 2.2.2, 6.2.1)* *LO 6.2: Compare the diverse applications of refrigeration and air conditioning and select appropriate control as per the application.(PI: 2.2.4, 6.3.1)*	
	Course Conclusion At the end of the course, students would be expected to be able to 1. Demonstrate the working principle of refrigerators and heat pumps. 2. Determine COP of various Refrigeration systems. 3. Use psychrometric processes to get the required comfort conditions 4. Conduct a heat load analysis to calculate the cooling load for a given application and select an appropriate air distribution system. 5. Understand the working principle of different controls and their applications.	
	Total	**45**

Performance Indicators:

PI No.	PI Statement
1.2.1	Apply laws of natural science to an engineering problem.
1.4.1	Apply mechanical engineering concepts to solve engineering problems.
2.1.2	Identify engineering systems, variables, and parameters to solve the problems.
2.2.2	Identify, assemble, and evaluate information and resources.
2.2.3	Identify existing processes/solution methods for solving the problem, including forming justified approximations and assumptions.
2.2.4	Compare and contrast alternative solution processes to select the best process.
2.4.1	Apply engineering mathematics and computations to solve mathematical models.
3.1.4	Extract engineering requirements from relevant engineering Codes and Standards.
3.1.6	Determine design objectives, functional requirements, and arrive at specifications.
6.2.1	Interpret legislation, regulations, codes, and standards relevant to your discipline and explain its contribution to the protection of the public.
6.3.1	Identify risks/impacts in the life cycle of an engineering product or activity.
6.3.2	Understand the relationship between the technical, socio-economic, and environmental dimensions of sustainability.
6.3.4	Apply principles of preventive engineering and sustainable development to an engineering activity or product relevant to the discipline
9.1.1	Read, understand, and interpret technical and non-technical information.
9.3.1	Create engineering-standard figures, reports, and drawings to complement writing and presentations.
9.3.2	Use a variety of media effectively to convey a message in a document or a presentation.

Course Outcomes: A learner will be able to -

1 Demonstrate an understanding of refrigerants designation and ODP, GWP, regulations and Protocols. *(LO 1.3, LO 1.4, LO 1.5, LO 1.6)*

2 Analyse various refrigeration systems and heat pump. (*LO1.1, LO 1.2, LO 2.1, LO 2.3, LO 2.4, LO 2.5)*

3 Interpret psychometric information and perform numerical analysis as per the comfort conditions required.(*LO 3.1, LO 3.2, LO 3.3 , LO 3.4, LO 3.5)*

4 Conduct a comprehensive cooling load analysis and design air conditioning systems integrating building survey. (*LO 4.1, LO 4.2, LO 4.3, LO 4.4, LO 4.5, LO 4.6)*

5 Design a sustainable air distribution system for minimum pressure loss and vibration. (*LO 5.1, LO 5.2, LO 5.3)*

6 Select appropriate control systems as per their industrial applications in refrigeration and air conditioning considering the risk /impact on the life cycle of the system.(*LO 2.2, LO 5.4, LO 6.1, LO 6.2)*

CO-PO Mapping Table with Correlation Level

CO ID	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MEPEC6022.1	2	3	--	--	--	3	--	--	3	--	--
MEPEC6022.2	3	2	--	--	--	--	--	--	--	--	--
MEPEC6022.3	3	3	--	--	--	3	--	--	3	--	--
MEPEC6022.4	3	3	3	--	--	3	--	--	--	--	--
MEPEC6022.5	3	2	--	--	--	2	--	--	--	--	--
MEPEC6022.6	--	3	--	--	--	3	--	--	--	--	--
Average	**3**	**3**	**3**	**--**	**--**	**3**	**--**	**--**	**3**	**--**	**--**

NOTE: CO can be mapped to PO at level 3 if at least two PIs are associated with that CO; otherwise, it can be mapped at level 2.

Text Books:

1. Refrigeration and air-conditioning – C P Arora, TMH
2. Refrigeration and Air-conditioning – R. K. Rajput
3. Refrigeration and air-conditioning – W F Stoeker and J W Jones, TMH
4. Modern Air-conditioning practice – C P Arora, TMH
5. Basic Refrigeration and air-conditioning- P.Ananthanarayana, TMH

Reference Books:

1. Principles of refrigeration – R J Dossat, Willey Eastern Publication
2. Introduction to Refrigeration and Air-Conditioning Systems - Allen T. Kirpatrick
3. ASHRAE Handbook of Systems
4. ASHRAE Handbook of Equipments
5. ISHRAE Air Conditioning Handbook

Other Resources:

1. NPTEL Course: Refrigeration and Air Conditioning by Prof. M. Ramgopal
   Prof. R.C. Arora, Department of Mechanical Engineering at IIT Kharagpur :-Web link- NPTEL :: Mechanical Engineering - Refrigeration and Air Conditioning
2. NPTEL Course: Refrigeration and Air Conditioning by Prof. Ravi Kumar
   Prof. R.C. Arora, Department of Mechanical Engineering at IIT Roorkee :-Web link- NPTEL :: Mechanical Engineering - NOC:Refrigeration and air-conditioning

IN-SEMESTER ASSESSMENT (50 MARKS)

1. Continuous Assessment – Theory (20 Marks)

Suggested breakup of distribution

One MCQ test as per GATE exam pattern/ level	:	05 Marks
One Class test	:	05 Marks
Flip classroom	:	05 Marks
Regularity and active participation	:	05 Marks

2. Mid Semester Exam (30 Marks)

Mid semester examination will be based on 40% to 50% syllabus.

END SEMESTER EXAMINATION (50 MARKS)

End Semester Examination will be based on syllabus coverage up to the Mid Semester Examination (MSE) carrying 20%-30% weightage, and the syllabus covered from MSE to ESE carrying 70%-80% weightage.

Course Type	Course Code	Course Name	Credits
PEC	MEPEC6023	CRYOGENIC ENGINEERING	03

Examination Scheme					
Distribution of Marks			Exam Duration (Hrs.)		Total Marks
In-semester Assessment		End Semester Examination (ESE)			
Continuous Assessment	Mid-Semester Exam (MSE)		MSE	ESE	
20	30	50	1.5	2	100

Pre-requisite:

1. MEPCC304 Thermodynamics
2. MEPCC407 Thermal Engineering

Program Outcomes addressed:

1. PO1: Engineering knowledge
2. PO2: Problem analysis
3. PO3: Design/development of solutions
4. PO4: Conduct investigations of complex problems
5 PO6: The Engineer and The World

Course Objectives:

1. To familiarize with refrigeration principles, including vapor compression cycles, refrigerants, air-refrigeration, Psychrometry, and human comfort in air conditioning.
2. To acquaint with cryogenic systems, low-temperature properties, gas liquefaction for Neon, Hydrogen, and Helium, and specialized refrigeration techniques like magnetic cooling and cryo-coolers.
3. To develop an understanding of cryogenic fluid storage and transfer systems, along with their design, operation, and applications in low-temperature engineering.

Module	Details	Hrs.
	Course Introduction This course provides a strong foundation in cryogenic engineering, focusing on low-temperature science and technology while integrating theoretical knowledge with mathematical accuracy for in-depth analysis and application of key concepts. By combining theoretical principles with practical applications, students develop problem-solving skills essential for research and advanced studies.	**01**
01.	**Introduction to refrigeration and refrigerants** ***Learning Objective/s:*** *To acquaint with the fundamental properties of refrigerants*	**6-8**

	To analyze the working and operating principles of air refrigeration systems for effective mechanical system design.	
	Contents: **1.1 Introduction to Refrigeration:** Carnot refrigerator, Carnot heat pump, Reversed Carnot cycle, unit of refrigeration, Co- efficient of Performance **1.2 Refrigerants**: Desirable properties of refrigerants, ASHRAE numbering system for refrigerants. Thermodynamic, Chemical and Physical properties, Secondary refrigerants, ODP and GWP, Montreal protocol and India's commitment, Recent substitutes for refrigerants. Nano-fluids and Phase Change Materials as refrigerant**.** **1.3 Air-refrigeration:** Bell Coleman cycle and its numerical.	
	Self-Learning Topics: *Selection of refrigerant*	
	Learning Outcomes: *A learner will be able to* *LO 1.1: Analyze the Carnot refrigerator and Carnot heat pump working principles to determine efficiency and performance, considering sustainability aspects. (PI 1.1.1, 6.2.3)* *LO 1.2: Apply thermodynamic principles to evaluate the Coefficient of Performance (COP) in refrigeration cycles, ensuring compliance with energy efficiency and environmental standards. (PI 1.2.1, 6.1.1)* *LO 1.3: Identify and classify different types of refrigerants based on thermodynamic, chemical, and physical properties, incorporating sustainability considerations. (PI 2.1.1, 6.1.3)* *LO 1.4: Compare the environmental impact of refrigerants using Ozone Depletion Potential (ODP) and Global Warming Potential (GWP) criteria to determine sustainable alternatives. (PI 2.2.3, 6.2.3)* *LO 1.5: Assess the impact of refrigerant selection on sustainability and regulatory compliance under the Montreal Protocol, ensuring alignment with global environmental policies. (PI 6.1.1)* *LO 1.6: Evaluate the feasibility of air-refrigeration systems like the Bell Coleman cycle for different engineering applications, considering energy efficiency and sustainability aspects. (PI 6.2.3)*	
02.	**Refrigeration Systems** ***Learning Objective/s:*** *To acquaint with the concept of the vapor refrigeration system and analyze vapor compression cycles effectively using P-h charts.* *To inculcate the concepts of thermal comfort and Psychrometry while evaluating the effects of sub-cooling and superheating on refrigeration performance.*	**8-10**
	Contents: **Vapour Compression Refrigeration System:** Simple vapour compression cycle, Effect of liquid sub cooling& superheating, effect of evaporator and condenser pressures, methods of sub-cooling, use of P-h charts, Use of P-h Charts. **Human Comfort**: Thermal exchange of body with environment, Effective temperature, Comfort chart, Comfort zone, Indoor Air	

	Quality, Green Buildings **Psychrometry:** Need for air conditioning, Principle of Psychrometry, Psychrometric properties, chart and processes, air washers, requirements of comfort air conditioning, Adiabatic air mixing, Psychrometric chart, RSHF, GSHF, ERSHF, Bypass factor process, Numerical based on Psychrometric chart and Apparatus dew point.	
	Self-Learning Topics: *Heat pump*	
	Learning Outcomes: *A learner will be able to* *LO 2.1: Apply thermodynamic principles to analyze the performance of the vapour compression refrigeration cycle and its components, considering energy efficiency and sustainability aspects. (PI 1.4.1, 6.2.3)* *LO 2.2: Compare different psychrometric processes and their application in human comfort, indoor air quality, and energy efficiency, incorporating sustainability considerations. (PI 2.2.3, 6.1.3)* *LO 2.3: Evaluate the effects of subcooling, superheating, evaporator, and condenser pressures on refrigeration system efficiency, ensuring optimal energy utilization and environmental sustainability. (PI 2.3.1, 6.2.3)* *LO 2.4: Design air conditioning systems using psychrometric principles to achieve thermal comfort and optimize energy efficiency while considering environmental regulations. (PI 3.1.6, 6.2.1)* *LO 2.5: Develop selection criteria for air-conditioning system components based on design requirements and operating conditions, ensuring compliance with green building standards. (PI 3.2.3, 6.2.3)* *LO 2.6: Interpret and utilize P-h charts to assess refrigeration cycle performance and determine critical operating parameters, ensuring alignment with sustainable engineering practices. (PI 4.3.1, 6.2.1)* *LO 2.7: Analyze experimental data from refrigeration and psychrometric systems to validate performance and efficiency improvements, ensuring compliance with sustainability guidelines. (PI 4.3.2, 6.1.1)* *LO 2.8: Assess the environmental impact and sustainability of refrigeration and air-conditioning systems concerning energy consumption and green building standards. (PI 6.2.3)*	
03.	**Introduction to Cryogenic Systems & Low Temperature Properties** ***Learning Objective/s:*** *To explore cryogenic systems' historical development and multifaceted industrial applications.* *To analyze low-temperature properties of engineering materials and cryogenic fluids.*	**9-11**
	Contents: **Introduction to Cryogenic Systems**: Historical development, Applications of Cryogenics (Space, Food Processing, Super conductivity, Electrical Power, Biology, Medicine, Electronics and Cutting Tool Industry). **Low Temperature Properties**: Properties of Engineering Materials (Mechanical properties, Thermal properties, Electric and Magnetic properties), Properties of Cryogenic fluids.	
	Self-Learning Topics:	

	Fundamentals of Material Science and Thermo-Physical Properties at Low Temperatures.	
	Learning Outcomes: *A learner will be able to* *LO 3.1: Apply advanced mathematical techniques to model and analyze the thermal and mechanical behavior of materials under cryogenic conditions, considering engineering sustainability aspects. (PI 1.1.2, 6.2.3)* *LO 3.2: Evaluate the properties of cryogenic fluids and engineering materials at low temperatures using scientific principles and engineering concepts, incorporating environmental and sustainability considerations. (PI 1.2.1, 6.1.1)* *LO 3.3: Formulate a structured understanding of cryogenic system applications and relate them to real-world engineering challenges, ensuring alignment with sustainable engineering practices. (PI 2.2.3, 6.1.3)* *LO 3.4: Identify and compare different applications of cryogenic technology in space, medicine, electronics, and industrial sectors based on feasibility, efficiency, and sustainability. (PI 2.3.1, 6.2.3)* *LO 3.5: Design cryogenic systems for applications like space exploration by integrating material properties, cryogenic fluids, and safety considerations with societal and environmental impacts. (PI 3.1.6, 6.2.1)* *LO 3.6: Develop optimized cryogenic cooling techniques for energy efficiency and enhanced system performance in industrial applications, ensuring minimal environmental impact. (PI 3.4.1, 6.2.3)* *LO 3.7: Assess the sustainability and societal impact of cryogenic applications in medicine, energy, and superconductivity, ensuring compliance with environmental regulations. (PI 6.1.1)* *LO 3.8: Analyze environmental and ethical considerations in the development and implementation of cryogenic technology, ensuring alignment with industry and regulatory standards. (PI 6.2.3)*	
04.	**Gas liquefaction System** ***Learning Objective/s:*** *To understand the principles of ideal liquefaction systems and their components.* *To analyze gas liquefaction systems for Neon, Hydrogen, and Helium.* *To understand the principles and operation of gas liquefaction systems, including Joule Thomson, adiabatic expansion, and Linde Hampson cycles.*	**5-7**
	Contents: **Introduction to Liquefaction Systems**: Ideal system, Joule Thomson expansion, Adiabatic expansion, Linde Hampson Cycle, Claude & Cascaded System. **Gas Liquefaction Systems**: General liquefaction systems. Liquefaction systems for Neon, Hydrogen and Helium. Critical components of liquefaction systems.	
	Self-Learning Topics: *Different insulating materials for specific applications*.	
	Learning Outcomes:	
	A learner will be able to *LO 4.1: Apply thermodynamic principles to analyze the performance of ideal gas liquefaction cycles, including Joule-Thomson and adiabatic expansion processes, while considering energy efficiency and sustainability. (PI 1.4.1, 6.2.3)* *LO 4.2: Evaluate the working principles of Linde Hampson, Claude, and cascaded liquefaction cycles using mathematical and scientific models to ensure efficient and sustainable operations. (PI 1.2.1, 6.1.1)*	

	LO 4.3: Formulate an understanding of gas liquefaction systems and their applications in industries such as aerospace, medical, and energy sectors, incorporating sustainability aspects. (PI 2.2.3, 6.1.3) *LO 4.4: Identify and compare the efficiency of different gas liquefaction methods for Neon, Hydrogen, and Helium based on theoretical modeling and industrial feasibility. (PI 2.3.1, 4.3.2)* *LO 4.5: Design gas liquefaction systems considering energy efficiency, component selection, and feasibility for industrial applications, while addressing environmental concerns. (PI 3.1.6, 6.2.1)* *LO 4.6: Develop optimization strategies for improving liquefaction system performance while minimizing energy losses and promoting sustainable engineering practices. (PI 3.4.1, 6.2.3)* *LO 4.7: Conduct investigations using thermodynamic models to assess the performance of liquefaction cycles and their components, ensuring reliable and sustainable operations. (PI 4.3.1, 6.1.1)* *LO 4.8: Analyze experimental data and simulation results to validate improvements in gas liquefaction efficiency, considering technical and environmental impacts. (PI 4.3.2, 6.2.3)* *LO 4.9: Assess the environmental and societal impacts of gas liquefaction systems with respect to energy consumption, sustainability, and safety. (PI 6.1.1)* *LO 4.10: Evaluate the ethical and regulatory considerations in the operation and design of gas liquefaction systems, ensuring compliance with industry and environmental standards. (PI 6.2.3)*	
05.	**Cryogenic refrigeration systems** ***Learning Objectives:*** *To analyze advanced cryogenic refrigeration systems, including Magnetic Cooling, Stirling Cycle, and Cryo Coolers for diverse applications.*	**5-7**
	Contents: **Introduction to Cryogenic Refrigeration Systems**: Magnetic Cooling, Stirling Cycle, Cryo Coolers. **Cryogenic Refrigeration Systems**: Ideal refrigeration systems, Refrigeration using liquids and gases as refrigerant, Refrigerators using solids as working media.	
	Self-Learning Topics: *Basics of Thermodynamic Cycles for Refrigeration and Heat Engines*	
	Learning Outcomes :	
	A learner will be able to *LO 5.1: Apply engineering principles to analyze cryogenic refrigeration systems, including magnetic cooling, Stirling cycle, and cryo coolers, while considering sustainability and energy efficiency. (PI 1.1.1, 6.2.3)* *LO 5.2: Evaluate the suitability of various refrigerants, including liquids, gases, and solids, for cryogenic refrigeration systems under specific conditions, ensuring compliance with environmental regulations. (PI 1.2.1, 6.1.1)* *LO 5.3: Identify and compare different cryogenic refrigeration techniques based on efficiency, feasibility, and application requirements, incorporating sustainability considerations. (PI 2.2.3, 6.1.3)* *LO 5.4: Analyze the thermal behavior and efficiency of cryogenic refrigeration cycles through theoretical modeling and data interpretation, ensuring alignment with sustainable engineering principles. (PI 2.3.2, 4.3.2)*	

	LO 5.5: Design cryogenic refrigeration systems by selecting appropriate refrigerants and components to ensure safety, efficiency, and adherence to sustainability-focused engineering standards. (PI 3.1.6, 6.2.1) *LO 5.6: Develop optimized strategies for improving cryogenic refrigeration system performance while minimizing energy losses and promoting environmental sustainability. (PI 3.4.1, 6.2.3)*	
06.	**Cryogenic Fluid Storage and Transfer Systems** ***Learning Objective:*** *To evaluate the design and performance of cryogenic storage vessels, insulation types, and fluid transfer systems effectively.*	**4-6**
	Contents: **Cryogenic storage vessels and transportation:** Thermal insulation and their performance at cryogenic temperatures, Super insulations, Vacuum insulation, Powder insulation. Cryogenic fluid transfer systems.	
	Self-Learning Topics: *Heat Transfer Mechanisms and Insulation Techniques in Low-Temperature Applications.*	
	Learning Outcomes: *A learner will be able to* *LO 6.1: Apply engineering principles to analyze the performance of thermal insulation systems for cryogenic storage and transportation, considering energy efficiency and sustainability. (PI 1.1.1, 6.2.3)* *LO 6.2: Identify and evaluate the factors affecting the efficiency of cryogenic storage vessels and fluid transfer systems under varying conditions, ensuring compliance with safety and environmental standards. (PI 1.2.1, 6.1.1)* *LO 6.3: Design cryogenic storage vessels and transfer systems with optimized insulation techniques to minimize thermal losses and enhance safety while addressing sustainability concerns. (PI 2.2.3, 6.1.3)* *LO 6.4: Analyze and compare the thermal performance of various insulation types for cryogenic applications based on theoretical principles and validated experimental data. (PI 2.3.2, 4.3.2)* *LO 6.5: Develop engineering strategies to enhance the efficiency of cryogenic insulation materials while ensuring compliance with industry standards and environmental considerations. (PI 3.1.6, 6.2.1)* *LO 6.6: Optimize the design of cryogenic storage and transfer systems to minimize energy loss, improve operational efficiency, and ensure sustainable engineering solutions. (PI 3.4.1, 6.2.3)*	
	Course Conclusion Upon completion, learner will be equipped to understand, design, and evaluate cryogenic systems, applying their knowledge to industrial sectors such as space technology, medical applications, and energy systems. This comprehensive understanding of cryogenics enables learners to contribute effectively to technological advancements and innovative engineering solutions.	**01**
	Total	**45**

Performance Indicators:

P.I. No.	P.I. Statement
1.1.1	Apply mathematical techniques such as calculus, linear algebra, and statistics to solve problems.
1.1.2	Apply advanced mathematical techniques to model and solve mechanical engineering problems.
1.2.1	Apply laws of natural science to an engineering problem.
1.4.1	Apply Mechanical engineering concepts to solve engineering problems.
2.1.1	Articulate problem statements and identify objectives.
2.2.3	Identify existing processes/solution methods for solving the problem, including forming justified approximations and assumptions.
2.3.1	Combine scientific principles and engineering concepts to formulate model/s (mathematical or otherwise) of a system or process that is appropriate in terms of applicability and required accuracy.
2.3.2	Identify assumptions (mathematical and physical) necessary to allow modelling of a system at the level of accuracy required.
3.1.6	Determine design objectives, functional requirements and arrive at specifications.
3.2.3	Identify suitable criteria for the evaluation of alternate design solutions.
3.4.1	Refine a conceptual design into a detailed design within the existing constraints of the resources.
4.3.1	Use appropriate procedures, tools and techniques to conduct experiments and collect data.
4.3.2	Analyze data for trends and correlations, stating possible errors and limitations.
6.1.1	Identify and describe various engineering roles, particularly as pertains to protection of the public and public interest at the global, regional, and local levels.
6.1.3	Understand the relationship between the technical, socio-economic and environmental dimensions of sustainability.
6.2.1	Interpret legislation, regulations, codes, and standards relevant to your discipline and explain its contribution to the protection of the public.
6.2.3	Apply principles of preventive engineering and sustainable development to an engineering activity or product relevant to the discipline.

Course Outcomes: A learner will be able to -

1. Analyze refrigeration systems, including air-refrigeration, vapour compression, and absorption cycles, while selecting appropriate refrigerants and evaluating psychrometric properties for efficiency, environmental impact, and sustainability. *(LO 1.1, LO 1.2, LO 1.3, LO 1.4, LO 1.5, LO 1.6, LO 2.1, LO 2.2, LO 2.3, LO 2.4, LO 2.5, LO 2.6, LO 2.7, LO 2.8)*

2. Examine cryogenics, its historical development, material properties at low temperatures, and its applications in aerospace, medical, and industrial sectors while considering safety, efficiency, and environmental impact. *(LO 3.1, LO 3.2, LO 3.3, LO 3.4, LO 3.5, LO 3.6, LO 3.7, LO 3.8)*

3. Evaluate gas liquefaction cycles (Joule-Thomson, Linde-Hampson, Claude, and cascaded) and their thermodynamic performance, efficiency, and key components under various conditions. *(LO 4.1, LO 4.2, LO 4.3, LO 4.4, LO 4.5, LO 4.6, LO 4.7, LO 4.8, LO 4.9, LO 4.10)*

4. Apply thermodynamic principles to optimize and design cryogenic refrigeration and liquefaction methods while ensuring efficiency, feasibility, safety, and sustainability. *(LO 5.1, LO 5.2, LO 5.3, LO 5.4, LO 5.5, LO 5.6)*

5. Assess cryogenic fluid storage and transport by applying engineering principles, analyzing insulation techniques, safety, thermodynamic modeling, and sustainability to meet regulatory standards. *(LO 6.1, LO 6.2, LO 6.3, LO 6.4, LO 6.5, LO 6.6)*

CO-PO Mapping Table with Correlation Level

CO ID	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MEPEC6023.1	3	3	3	3	--	3	--	--	--	--	--
MEPEC6023.2	3	3	3	--	--	3	--	--	--	--	--
MEPEC6023.3	3	3	3	3	--	3	--	--	--	--	--
MEPEC6023.4	3	3	3	--	--	3	--	--	--	--	--
MEPEC6023.5	3	3	3	--	--	3	--	--	--	--	-
Average	**3**	**3**	**3**	**3**	**--**	**3**	**--**	**--**	**--**	**--**	**--**

NOTE: CO can be mapped to PO at level 3 if at least two PIs are associated with that CO; otherwise, it can be mapped at level 2.

Text Books :

1. Randall F. Barron, “Cryogenics Systems”, Second Edition, Oxford University Press, New (1985).
2. Thomas M. Flynn, “Cryogenic Engineering”, second edition, CRC press, New York (2005)
3. R. B. Scott, Cryogenic Engineering, Van Nostrand Co., 1959

Reference Books :

1. Klaus D.Timmerhaus and Thomas M.Flynn, Cryogenic Process Engineering, Plenum Press,1989.
2. Tom Bradshaw, Beth Evans, John Vandore, Cryogenics –Fundamentals, Foundations and applications, IOP Publishing, Bristol, UK, 2022
3. Cryogenic technology & applications, A R Jha, Butterworth-Heinemann

Other Resources :

1. NPTEL Course: Cryogenic Engineering by IIT Bombay Web link- https://archive.nptel.ac.in/courses/112/101/112101004/

IN-SEMESTER ASSESSMENT (50 MARKS)

1. **Continuous Assessment (20 Marks)**

Active participation in Industrial Visit and Report	:	05 Marks
Case study/ Assignments	:	05 Marks
Class Tests	:	05 Marks
Regularity and active participation	:	05 Marks

2. **Mid Semester Exam (30 Marks)**

Mid semester examination will be based on 40% to 50% syllabus.

END SEMESTER EXAMINATION (50 MARKS)

End Semester Examination will be based on syllabus coverage up to the Mid Semester Examination (MSE) carrying 20%-30% weightage, and the syllabus covered from MSE to ESE carrying 70%-80% weightage.

Course Type	Course Code	Course Name	Credits
LBC	MELBC609	MACHINE DESIGN LABORATORY	02

Examination Scheme		
Continuous Assessment	**End Semester Exam (ESE)**	**Total**
25	25	50

Pre-requisite :

1. ESE 101 Engineering Mechanics
2. MEPCC302 Mechanics of Solid
3. MEPCC303 Material Science and Engineering
4. MEPCC406 Theory of Machine
5. MEPCC408 Manufacturing Technology

Program Outcomes addressed :

1. PO2: Problem analysis
2. PO3: Design/development of solutions
3. PO4: Conduct investigations of complex problems
4. PO5: Engineering tool usage
5. PO8: Individual and Collaborative Team work
6. PO9: Communication

Course Objectives:

1. Familiarize students to the use of design data books & various codes of practice for the design/selection of standard machine elements.
2. Guide students through the design calculation, preparation of working drawings of actual design model.
3. Equip students with the basic of modelling software, part design and assembly making.

Module	Detailed Contents	Hrs
	Course Introduction This lab course introduces students to the design of mechanical components such as shafts, keys, and couplings. Students will use modern engineering tools and computational methods to model and analyses the mechanical components/systems while adhering to industry standards. Through practical task and design projects, they will assess design parameters, stress, deformation, and performance characteristics, ensuring efficient and reliable solutions. This hands-on experience prepares students to effectively translate theoretical knowledge into practical engineering applications, equipping them for real-world challenges in mechanical system design.	**01**
	Learning Objective/s:	

01.	*To design machine elements with functional and strength design principle.* *To get acquainted to the design procedure of the Knuckle Joint / Cotter, Shaft, Screw Jack, Bush pin coupling.* *To select the materials and design stresses* *To identify the resisting areas for all possible modes of failure*	**15**
	Tasks: i. Design a Knuckle Joint / Cotter Joint to connect two rods of equal diameter subjected to an axial tensile force. ii. Design shaft under various conditions and to determine the shaft diameter using ASME code. iii. Design a screw jack for the given load carrying capacity and lifting height. iv. Design a bushed-pin type of flexible coupling for the given specification.	
	Self-Learning Topics:	
	Learning Outcomes : *A learner will be able to* *LO 1.1: Design the knuckle joint / cotter joint using the empirical relations subjected to load condition (PI 2.1.3, PI 3.1.6, PI 5.1.1, PI 9.3.1)* *LO 1.2: Design a shaft subjected to static load condition and fatigue criteria. (PI 2.3.1, PI 3.1.6, PI 5.1.1, PI 9.1.2)* *LO 1.3: Design all the components of screw jack and check for the various failure criteria. (PI 2.4.1, PI 3.1.6, PI 5.3.2, PI 8.2.1, PI 9.1.1)* *LO 1.4: Design all the components of coupling and check for the various failure criteria. (PI 2.3.1, PI 2.4.4, PI 3.3.1, PI 5.2.1, PI 8.2.1, PI 9.3.1)*	
02.	***Learning Objective/s:*** *To prepare the working drawings of machine elements based on the design calculations and perform FEA analysis.* *To get acquainted to the conversion of design dimensions into manufacturing / working drawing using modeling software.* *Perform the FEA analysis of the modelled components using simulation software.* *To perform design exercises in the form of design calculations.*	**14**
	Tasks: i. Convert design dimensions of knuckle joint/cotter joint into manufacturing / working drawing using modeling software. ii. Perform the FEA analysis of the modelled components using simulation software. iii. Design exercises in the form of design calculations with sketches and/ or drawings	

	on bolted joints, bearings and belt machine elements.	
	Self-Learning Topics:	
	Learning Outcomes: *A learner will be able to* *LO 2.1: Convert design dimensions into manufacturing drawing and model the components and system using modeling software. (PI 3.3.1, PI 4.1.3, PI 5.1.2, PI 7.1.1, PI 7.2.1)* *LO 2.2: Analyze the modelled component/system using finite element analysis (FEA) simulations. (PI 3.1.4, PI 2.4.2, PI 2.4.4, PI 4.3.1, PI 5.3.2)* *LO 2.3: Interpret and evaluate post-processing results, including stress distribution, deformation to assess the structural integrity of machine element. (PI 2.4.4, PI 4.3.3, PI 5.2.1, PI 7.2.1)* *LO 2.4: Extract the data from a design data book like PSG and use it for the designing of the mechanical components. (PI 2.4.4, PI 3.1.4, PI 3.1.6)*	
	Total	**30**

Performance Indicators:

P.I. No.	**P.I. Statement**
2.1.3	Identify the mathematical, engineering and other relevant knowledge that applies to a given problem
2.3.1	Combine scientific principles and engineering concepts to formulate model/s (mathematical or otherwise) of a system or process that is appropriate in terms of applicability and required accuracy.
2.4.1	Apply engineering mathematics and computations to solve mathematical models
2.4.2	Produce and validate results through skilful use of contemporary engineering tools and models.
2.4.4	Extract desired understanding and conclusions consistent with objectives and limitations of the analysis.
3.1.4	Extract engineering requirements from relevant engineering Codes and Standards such as ASME, ASTM, BIS, ISO and ASHR
3.1.6	Determine design objectives, functional requirements and arrive at specifications
3.3.1	Apply formal decision-making tools to select optimal engineering design solutions for further development.
4.1.3	Apply appropriate instrumentation and/or software tools to make measurements of physical quantities
4.3.1	Use appropriate procedures, tools, and techniques to conduct experiments and collect data.
4.3.3	Represent data (in tabular and/or graphical forms) so as to facilitate analysis and explanation of the data and drawing of conclusions.
5.1.1	Identify modern engineering tools such as computer-aided drafting, modeling, and analysis; techniques and resources for engineering activities.
5.1.2	Create/adapt/modify/extend tools and techniques to solve engineering problems

5.2.1	Identify the strengths and limitations of tools for (i) acquiring information, (ii) modeling and simulating, (iii) monitoring system performance, and (iv) creating engineering designs.
5.3.2	Verify the credibility of results from tool use with reference to the accuracy and limitations, and the assumptions inherent in their use.
7.1.1	Identify situations of unethical professional conduct and propose ethical alternatives
7.2.1	Identify tenets of the ASME professional code of ethics
8.2.1	Identify tenets of the ASME professional code of ethics.
9.1.1	Implement the norms of practice (e.g., rules, roles, charters, agendas, etc.) of effective teamwork to accomplish a goal.
9.1.2	Implement the norms of practice (e.g. rules, roles, charters, agendas, etc.) of effective team work, to accomplish a goal.
9.3.1	Present results as a team, with smooth integration of contributions from all individual efforts.

Course Outcomes: A learner will be able …….

1. To design shaft, knuckle Joint, cotter joint under various conditions by selecting suitable materials, design stresses. *(LO 1.1, LO 1.2)*
2. To design screw jack and flexible flange couplings under various conditions by selecting suitable materials and design stresses. *(LO 1.3, LO 1.4)*
3. To convert design dimensions into working/manufacturing drawing of knuckle joint/cotter joints and flexible flange couplings. *(LO 2.1, LO 2.2, LO 2.3)*
4. To use the design data book/standard codes to standardise the designed dimensions. *(LO 1.1, LO 1.2, LO 1.3, LO 1.4, LO 2.4)*

CO-PO Mapping Table with Correlation Level

CO ID	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MELBC609.1	--	3	3	--	3	--	--	--	3	--	--
MELBC609.2	--	3	3	--	3	--	--	2	3	--	--
MELBC609.3	--	3	3	3	3	--	3	--	--	--	--
MELBC609.4	--	3	3	--	3	--	--	2	3	--	--
Average	--	**3**	**3**	**3**	**3**	--	--	**2**	**3**	--	--

NOTE: CO can be mapped to PO at level 3 if at least two PIs are associated with that CO; otherwise, it can be mapped at level 2.

Text Books :

1. Design of Machine Elements - V.B. Bhandari, Second edition, 2007, Tata McGraw Hill Publication
2. Design of Machine Elements – C.S. Sharma and Kamlesh Purohit. 2009, Prentice Hall India Publication
3. Machine Design by N. C. Pandya and C. S. Shah, 2006, Charotar Publishing House Pvt. Limited.
4. Machine Design by R. S. Khurmi and J.K. Gupta, 2007, S. Chand and company Ltd.

Reference Books :

1. Machine Design -An Integrated Approach - Robert L. Norton, Second edition, 2006, Pearson Education
2. Mechanical Engineering Design by Joseph Edward Shigley, Charles R. Mischke and Richard Gordon Budynas, 2004, McGraw Hill Publication
3. Design Data: Data Book of Engineers by PSG College,2020, Kalaikathir, Achchagam-Coimbatore

IN-SEMESTER ASSESSMENT (25 MARKS)

1. **Continuous Assessment (25 Marks)**

Suggested breakup of distribution

- Performance based on completion of task (Marks will be awarded to students based on task performance with proper understanding) : 15 Marks
- Course Project (max 4 students) : 05 Marks
  Design of any mechanical system consisting of four to five mechanical elements.

- Regularity and Active Participation : 05 Marks

END SEMESTER EXAMINATION (25 MARKS)

Students will be assessed based on

- Performance in the design task
- Oral

- Students will be randomly allocated a design task from the list of tasks performed during the semester (or any other similar task) and will be asked to write brief procedure related to the execution of the task including the diagram and/or calculation if any. The procedure and/or calculation is checked by the examiners (Internal and External) and evaluated out of 15 Marks.
- The students will be allocated 1 hour to complete the execution.
- Students will then be appearing for Oral in front of both Internal and External examiners. The weightage of oral examination which will be evaluated of 10 Marks

Two examiners, one Internal and one External will do the evaluation.

Course Type	Course Code	Course Name	Credits
SBL	MESBL603	CNC AND 3D PRINTING LABORATORY	02

Examination Scheme					
Distribution of Marks			Exam Duration (Hrs.)		Total Marks
In-semester Assessment		End Semester Examination (ESE)			
Continuous Assessment	Mid-Semester Exam (MSE)		MSE	ESE	
50	--	50	--	02	100

Pre-requisite:

1. MESBL402 CAD Modeling
2. MEPCC408 Manufacturing Technology

Program Outcomes addressed:

1. PO3: Design/Development of Solutions
2. PO4: Conduct investigations of complex problems
3. PO5: Engineering tool usage
4. PO8: Individual and Collaborative Team work
5. PO9: Communication

Course Objectives:

1. To familiarize students with part programming for tool path generation for machining operations, using G-M codes.
2. To make students acquaint with developing tool path from CAD to CAM system, using computer aided tool.
3. To prepare students for developing a 3D printed part using, FDM technique from CAD data.
4. To enable students to know the process of interpreting and processing medical scan data.

Module	Details	Hrs.
	Course Introduction This lab course equips students with practical skills that are directly applicable to a wide range of industries, including automotive, aerospace, healthcare, and consumer products. This course is essential as it bridges the gap between traditional and modern manufacturing techniques, offering hands-on experience with both CNC programming and 3D printing technologies. By learning both CNC programming and 3D printing, students gain understanding of modern manufacturing, and prototyping cycles, in real-world applications.	**01**
01.	**Part A: - CNC part Programming** **Tool path generation for machining operations, using GM code part programming.** ***Learning Objective:***	**5-6**

	To get acquainted with the basics of GM code part programming for developing tool paths for various machining operations.	
	Contents: Introduction to 2 and 3 axis CNC machines, importance of tool path generation for machining operations, coordinate system, setting of work zero and machine zero, basics of manual part programming for tool path generation using G-M codes, Canned cycles, manual part programming using G-M codes for developing a tool path for drilling, milling and similar machining operations. Coordinate system and setting of work zero and machine zero for CNC lathe machines, manual part programming using G-M codes for developing a tool path for machining operations like, facing, turning, taper turning, radius turning, thread cutting, chamfer, etc.	
	Self-Learning Topics: *Constructional details of CNC machines.*	
	Learning Outcomes: **Task: Develop the tool path for drilling, milling, and turning types of machining operations using GM codes, considering following points.** 1. Set up coordinate system, prepare the part geometry diagram as per the coordinate system. 2. Select cutting tools required for given machining operations, refer standard machining data and calculate speed and feed for the same. 3. Use G-M codes, and various CANNED cycles to develop a required tool path. (Total 3 experiments: - one of each on drilling, milling, and turning types of machining operations) *A learner will be able to* *LO 1.1: Develop an appropriate tool path using GM codes, for given data. (PI 3.1.3, 3.1.4, 3.1.6, 4.3.1, 4.3.4, 9.1.1, 9.3.1)*	
02.	**Tool path generation for machining operations, from CAD to CAM system, using computer aided tool.** ***Learning Objective:*** *To get familiarize with the use of computer aided tools like Autodesk Fusion 360 to create tool path for various machining operations, directly from CAD data.*	**6-7**
	Contents: **I. CAM Workspace** 1. Introduction to CAM Workspace, workflow in the CAM environment, creating a new CAM project, stock material setup, coordinate systems and machine setup, setting of work piece orientation, home position. 2. Creating Basic and Advance level toolpaths, tool selection, creating basic level 2D toolpaths like 2D contour, 2D pocket, drilling, tapping, turning, facing, canned cycles, etc., use of advanced toolpath strategies like adaptive clearing, 3D Contour, etc. 3. Post-Processing and G-code Generation, selecting and configuring post-processors in CAM workspace, simulating toolpaths, generating G-code for CNC machining, steps to export G-code to machine controllers. **II. A case study or video demonstration on Part Programming Simulation:** A case study or video demonstration on part programming	

	simulation for any non-conventional machining process (electric discharge machining, laser cutting machining, plasma cutting machining etc.)	
	Self-Learning Topics: *Various computer aided tools available for assisting CAD data to CAM systems.*	
	Learning Outcomes: **Task: generate the tool path for drilling, milling, and turning types of machining operations using CAD to CAM systems, considering following points**. 1. Create CAD model of the required finished part, call the finished part in CAM environment, set up stock size, work piece orientation, coordinate systems and home position for the given part**.** 2. Generate, simulate, verify and post process the tool paths for machining operations, using Fusion 360. (Total 3 experiments: - one of each on drilling, milling, and turning types of machining operations) *A learner will be able to* *LO 2.1: Synthesize CAD to CAM data to simulate the tool path, and verify the same for the correctness (PI 3.1.3, 3.1.6, 4.3.1, 4.3.4, 5.1.1, 5.1.2, 5.2.2, 9.1.2, 9.1.3)* **Task: A task based group activity, After MSE-(max 4 students in one group), based on part programming simulation for any non-conventional machining process.** (Total 1 Task/experiment) *A learner will be able to* *LO 2.2: Identify, read and summarize one case study/ an article (from a quality journal/ conference/ research paper) or video demonstration, on a simulation approach, for any non-conventional machining process. (PI 3.1.1, 3.1.3, 8.3.1, 9.1.1, 9.3.2)*	
03.	**Part B: - Introduction to 3D printing** ***Learning Objective:*** *To get acquainted with 3D printing process sequence, pre-processing, actual printing and post processing using FDM technique.*	**9-10**
	Contents: **I. 3D printing process sequence** Overview of 3D printing process sequence, introduction to FDM printing method, steps in product development from CAD to FDM 3D printed structure. Software used in this process. FDM machine construction details. **II. Development of a 3D printed structure using FDM** Creating CAD parts, converting CAD file to file formats like. stl, .obj, etc., using product data exchange, refinement of. stl file, processing. stl file in 3D printing FDM software, part orientation and manipulation, Filament Setting, Slicing Setting, printing parameters settings. File transfer from software to machine, Part printing and post processing	
	Self-Learning Topics: *Various other 3D printing processes*	
	Learning Outcomes: **Task: To develop a 3D printed object by FDM approach, considering following points,** 1. Create a CAD model of a part/component to be 3D printed by FDM technique,	

	convert the CAD part to. stl file format, check and repair. stl file. 2. Perform preprocessing of .stl file using FDM based 3D printing software. 3. 3. set up alternative part orientation, and support structure settings, in a FDM based 3D printing software and select the most suitable orientation with respect to printing time and material consumption. 4. Develop G – Code output from preprocessing step, Print the 3D part using FDM method and perform post processing of the 3D printed part. (Total 2 experiments) *A learner will be able to* *LO 3.1*: *Create a 3D model in CAD environment and process the 3D model for printing the same object. (PI 3.1.3, 3.1.6, 3.2.2, 3.2.3, 4.3.1, 4.3.2, 4.3.4, 5.1.1, 5.1.2, 5.2.2, 9.1.2, 9.1.3, 9.3.1)*	
04.	**Part C: Introduction to Bio modeling** ***Learning Objectives:*** *To get acquainted with steps of medical modeling and scan data processing.*	**6-7**
	Contents: **I. Overview of bio modeling process** Introduction to biomedical scanning methods, reading and interpreting DICOM files using sample files in software. **II. Development of a 3D printed structure from DICOM files** Creation of 3D model from 2D images using any image processing software like, 3D Slicer (open source). Data Acquisition, Data Processing tools like, volume rendering, segmentation, thresholding, scissors, etc., generation of GM codes, file transfer to FDM machine, and 3D printing for a bio medical application.	
	Self-Learning Topics: *Methods of medical imaging.*	
	Learning Outcomes: **Task: Read and interpret any sample DICOM file (scan data). Process DICOM data, to develop a 3D printed object by FDM approach, considering following points,** 1. read and interpret the sample anatomical data from available DICOM files. 2. Process the DICOM file to extract a particular anatomical structure using data processing tools and prepare .stl file from the same. 3. Check and repair .stl files, preprocess the. stl file in a FDM based 3D printing software, 4. Develop G code output, and data transfer to FDM based 3D printer for actual printing, and post processing of printed part. (Minimum 1 experiment) *A learner will be able to* *LO 4.1: Create a 3D model using biomedical scan data and process the same for 3D printing. (PI 3.1.3, 3.1.6, 4.3.1, 4.3.2, 4.3.4, 5.1.2.5.2.2, 9.1.1, 9.1.2, 9.1.3, 9.3.1)*	
	Course Conclusion	**01**
	Total	**60**
Total Minimum 10 experiments		

Performance Indicators:

P.I. No.	P.I. Statement
3.1.3	Synthesize engineering requirements from a review of the state-of-the-art
3.1.4	Extract engineering requirements from relevant engineering Codes and Standards such as ASME, ASTM, BIS, ISO and ASHRAE.
3.1.6	Determine design objectives, functional requirements and arrive at specifications
3.2.2	Build models/prototypes to develop a diverse set of design solutions
3.2.3	Identify suitable criteria for the evaluation of alternate design solutions
4.3.1	Use appropriate procedures, tools and techniques to conduct experiments and collect data
4.3.2	Analyze data for trends and correlations, stating possible errors and limitations
4.3.4	Synthesize information and knowledge about the problem from the raw data to reach appropriate conclusions
5.1.1	Identify modern engineering tools such as computer-aided drafting, modeling and analysis; techniques and resources for engineering activities.
5.1.2	Create/adapt/modify/extend tools and techniques to solve engineering problems
5.2.2	Demonstrate proficiency in using discipline-specific tools
8.3.1	Present results as a team, with smooth integration of contributions from all individual efforts
9.1.1	Read, understand and interpret technical and non-technical information
9.1.2	Produce clear, well-constructed, and well-supported written engineering documents
9.1.3	Create flow in a document or presentation - a logical progression of ideas so that the main point is clear
9.3.1	Create engineering-standard figures, reports and drawings to complement writing and presentations
9.3.2	Use a variety of media effectively to convey a message in a document or a presentation

Course Outcomes: A learner will be able to -

1. Develop a tool path for specific machining operations using part programming with G-M codes. *(LO 1.1)*
2. Generate CAM tool-path for specific machining operations from CAD Data. (*LO 2.1, LO 2.2)*
3. Create a 3D model of any real life object, in CAD environment and process the same for 3D printing. *(LO 3.1)*
4. Create a 3D model using biomedical scan data and process the same for 3D printing. *(LO 4.1)*

CO-PO Mapping Table with Correlation Level

CO ID	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MESBL603.1	--	--	3	3	--	--	--	--	3	--	--
MESBL603.2	--	--	3	3	3	--	--	2	3	--	--
MESBL603.3	--	--	3	3	3	--	--	--	3	--	--
MESBL603.4	--	--	3	3	3	--	--	--	3	--	--

Average	--	--	**3**	**3**	**3**	--	--	**2**	**3**	--	--

NOTE: CO can be mapped to PO at level 3 if at least two PIs are associated with that CO; otherwise, it can be mapped at level 2.

Text Books :

1. CAD/CAM Principles and Applications, P. N. Rao, Tata McGraw Hill Publications.
2. CAD / CAM and Automation, Farazdak Haideri , Nirali Prakashan.
3. CNC Technology and Programming, Krar, S., and Gill, A., McGraw Hill Publishers.

Reference Books :

1. Medical Modeling The Application of Advanced Design and Rapid Prototyping Techniques in Medicine, Richard Bibb, Dominic Eggbeer and Abby Paterson, Woodhead Publishing Series in Biomaterials: Number 91, Elsevier Ltd.
2. Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing, I. Gibson l D. W. Rosen l B. Stucker, Springer Publication

Other Resources :

1. NPTEL Course: Computer numerical control (CNC) of machine tools and processes, IIT Kharagpur Prof. Asimava Roy Choudhury. Web link:- https://nptel.ac.in/courses/112105211
2. NPTEL Course: Fundamentals of Additive Manufacturing Technologies, IIT Guwahati, Prof. Sajan Kapil. Web link:- https://nptel.ac.in/courses/112103306

IN-SEMESTER ASSESSMENT (50 MARKS)

1. Continuous Assessment - (30 Marks)

Suggested breakup of distribution

Practical performance based on all the experiments mentioned in the syllabus with proper understanding- 15 Marks
A task based group activity - Article reading and summarization: 10 Marks
Regularity and active participation: 5 marks

2. Practical Test (20 Marks)

- The test will be conducted after 40 % of the syllabus.
- Practical test of 1-hour duration to be conducted by Internal Examiner, based on developing tool paths for machining operations, from CAD to CAM systems.
- Evaluation of practical examination to be done by examiner, based on the printout of student’ s work.

END SEMESTER EXAMINATION (50 MARKS)

Students will be assessed based on three parameters:

- GM codes part programming knowledge,
- CAD to CAM Skills, Skills of 3D printing software, Skills of Slicer (open source) software,
- Oral

Students will be randomly allocated with two tasks based on experiments covered in syllabus during the semester.
Students will be getting 2 Hours to complete the task. Additional 10 minutes will be allocated for printouts.
Two examiners, one Internal and one External will do the evaluation, based on printout and oral exam.
The evaluation breakup is given below:

- Task 1: 20 Marks.
- Task 2: 20 Marks.
- Oral Examination: 10 Marks.

Course Type	Course Code	Course Name	Credits
MNP	MEMNP604	MINI PROJECT- 2B	01

Program Outcomes addressed:

1. PO1: Engineering Knowledge
2. PO2: Problem Analysis
3. PO3: Design/Development of Solutions
4. PO4: Conduct Investigations of Complex Problems
5. PO5: Engineering Tool Usage
6. PO6: The Engineer and The World
7. PO7: Ethics
8. PO8: Individual and Collaborative Team work
9. PO9: Communication
10. PO10: Project Management and Finance
11. PO11: Life-Long Learning

Course Objectives:

1. To guide students in identifying societal or research needs and formulating them into problem statements.
2. To facilitate problem-solving in group settings.
3. To apply basic engineering principles to address identified problems.
4. To foster self-learning and research skills.

Course Outcomes:

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

1. Identify problems based on societal or research needs and methodology for solving them.
2. Apply knowledge and skills to solve societal problems collaboratively.
3. Develop interpersonal skills necessary for teamwork.
4. Analyze, verify, and validate results effectively through various methodologies, including, test cases/benchmark data/theoretical/inferences/experiments/simulations, etc.
5. Evaluate the societal and environmental impacts of proposed solutions.
6. Adhere to standard engineering practices.
7. Excel in written and oral communication by technical report writing, oral presentation, and publishing results in
   - Research/white paper/article/blog writing/publication, etc.
   - Business plan for entrepreneurship product creation
   - Patent filing/copyright.
8. Gain technical competencies by participating in competitions, hackathons, etc.
9. Demonstrate lifelong learning capabilities through self-directed group projects.
10. Apply project management principles effectively.

Guidelines for the Mini Project
Mini project may be carried out in one or more form of following: Product preparations, prototype development model, fabrication of set-ups, laboratory experiment development, process modification/development, simulation, software development, integration of

software (frontend-backend) and hardware, statistical data analysis, creating awareness in society/environment etc.

- Students must form groups of 3 to 4 members either from the same or from different departments.
- Groups should conduct surveys to identify needs and develop problem statements in consultation with faculty.
- An implementation plan in Gantt/PERT/CPM chart format covering weekly activities must be submitted.
- Each group must maintain a logbook to record weekly progress, to be verified by the faculty supervisor.
- Faculty input should emphasize guiding by faculty and self-learning by group members.
- Groups should propose multiple solutions, select the best one in consultation with the supervisor, and develop a working model.
- The solution to be validated with proper justification and report to be compiled in standard format of the Institute. Software requirement specification (SRS) documents, research papers, competition certificates may be submitted as part of annexure to the report.
- With the focus on self-learning, innovation, addressing societal/research/innovation problems and entrepreneurship quality development within the students through the Mini Projects, it is preferable that a single project of appropriate level and quality be carried out in two semesters by all the groups of the students.
- However, based on the individual students or group capability, with the mentor's recommendations, if the proposed Mini Project adhering to the qualitative aspects mentioned above, gets completed in odd semester, then that group can be allowed to work on the extension of the Mini Project with suitable improvements/modifications or a completely new project idea in even semester. This policy can be adopted on a case by case basis.

In-Semester Continuous Assessment and End-Semester Examination Guidelines

- The Head of the Departments will assign a guide to each of the mini-projects and shall form a progress monitoring committee. The guide will carry out weekly monitoring of the project's progress. The committee shall carry out in-semester project evaluation based on presentations with a minimum of two evaluations per semester.
- Assessment will be based on individual contributions, understanding, and responses to questions asked.
- Continuous Assessment marks distribution in semester V (50 marks):
    - 05 marks for the Topic Approval Presentation in front of the progress monitoring committee
    - 15 marks for the Mid-Semester Progress Presentation in front of the progress monitoring committee
    - 25 marks for the Final Report & Presentation
    - 05 marks for Regularity and Active participation
- Continuous Assessment marks distribution in semester VI (50 marks):
    - 15 marks for the In-Semester Two Presentations
    - 05 marks for Participation in Project Competitions, TPP, etc.
    - 25 marks for the Final Report & Presentation
    - 05 marks for Regularity and Active participation

The review/progress monitoring committee will assess projects based on the following criteria.

Semester V:

- Theoretical solution completion, including component/system selection/design of software solution and cost analysis.
- Two reviews will occur:

- The first review will focus on finalizing the problem statement (topic approval).
- The second review will centre on finalizing the proposed solution.

Semester VI:

- Expected tasks include procuring components/systems, constructing a working prototype, and validating results based on prior semester work.
- Reviews will be conducted as follows:
  - The first review will assess the readiness to build a working prototype.
  - The second review will involve a poster presentation and demonstration of the working model in the last month of the semester.

In addition to above mentioned points, the following performance criteria shall be included during in-semester continuous assessment:

1. Quality of survey and need identification.
2. Clarity and innovativeness in problem definition and solutions.
3. Requirement gathering via SRS/feasibility study, cost-effectiveness, and societal impact of proposed solutions.
4. Completeness and full functioning of the working model.
5. Effective use of skill sets and engineering norms.
6. Verification & validation of the solutions/test cases.
7. Individual contributions to the group.
8. Clarity in written and oral communication.
9. Participation in technical paper presentation/project competitions/hackathon competitions, etc.

End-Semester Examination in Semester VI (50 marks):

1. Presentation and demonstration to internal and external examiners: 20 marks.
2. Emphasis on problem clarity, innovativeness, societal impact, functioning of the model, skill utilization, and communication clarity: 30 marks.

Course Type	Course Code	Course Name	Credits
ELC	ELC601	Research Methodology	02

Examination Scheme					
Distribution of Marks			Exam Duration (Hrs.)		Total Marks
In-semester Assessment		End Semester Exam (ESE)			
Continuous Assessment	Mid-Semester Exam (MSE)		MSE	ESE	
50	--	--	--	--	50

Program Outcomes addressed:

1. PO1: Engineering knowledge
2. PO2: Problem analysis
3. PO6: The Engineer and The World.
4. PO7: Ethics
5. PO8: Individual and Collaborative Team Work
6. PO9: Communication
7. PO11: Life-long learning

Course Objectives:

1. To gain the knowledge of use research tools and techniques to design research projects and form the hypothesis.
2. To familiarize students about the literature review practice for identifying the research gap.
3. To gain the knowledge about collection of data and qualitative/ quantitative analysis of data and results
4. To understand the key practices in preparation of a research report / paper.
5. To foster ethical practices in research and publications

Module	Details	Hrs
00	**Course Introduction:** This course aims to introduce students to the important aspects of research. The course is intended to make students aware of formal research and to overcome common misconceptions in research that may be present in their minds. At the end of this course, students shall be able to take up research activities in a more systematic and formal manner right from the beginning. This course on Research Methodology learned through experiential learning mechanism can play a significant and holistic role in contributing to the personal and professional development of students.	1
1	**Fundamentals of Research Methodology**	4-5
	Content: Types of Research, Research approaches, Empirical research methods, Significance of research, Research design, Case study method,	

	Sampling technique, Sources of data, Selection of research problem, Research Ethics and Empiricism *Exercise: A group discussion on what is research and ethics in research with related case studies shall be conducted.*	
2	**Formulation of a Research Problem & Hypothesis formulation**	**4-5**
	Content: Selection and formulation of a research problem, Objectives of formulation, Criteria of a good research problem, Literature Review Process and Formulation of Research Questions Hypothesis-Characteristics and Hypothesis Testing –Logic and Importance *Exercise: Groups of students shall make Technical Presentations on Selection of a research problem and Hypothesis formulations based on topics given.*	
3	**Research Design**	**4-5**
	Content: The Research framework, Research design: Need, Characteristics & Components; Experimental and non-experimental designs, Experimental and non-experimental hypothesis testing. Classification schemes for research design, Principles of experimental designs, Writing rationale for a research *Exercise: Students shall prepare the framework of research methods and techniques to conduct a study on a given real life case study covering key elements of the module.*	
4	**Sampling Method**	**3-4**
	Content: Probability or random sampling, Cluster sampling, Area sampling, Multi-stage sub-sampling, Random sampling with probability proportional to size, Non-probability sampling. *Exercise: A real life case study shall be demonstrated to students covering key elements of the module shall be covered.*	
5	**Data Collection & Data Analysis**	**4-5**
	Content: Sources of data, Collection of data, Measurement and scaling technique, Collection of data from appropriate sources (primary and secondary), Correlation and causation, Classification of quantitative analysis. Selection and analysis of multi-variate methods, Performing data analysis and presentation of results, Case study method.	

	Exercise: Group of students shall carry out exercise of real life data collection on a given research problem and data analysis and submit the report	
6	**Report Writing and Journal Publication**	**3-4**
	Content: Preparation of a research report, Formats and Contents of report: Literature review, Presentation of research work, Research Design & Analysis, Results, Findings, and Contribution, Significance of research, and Conclusion. Mechanics of writing papers in Peer-reviewed Journals / Reputed Conferences. Ethics in Publication. *Exercise: Students shall prepare & submit a paper (4-5 pages) in a standard format (suitable universally accepted journal publication format) based on the exercises / research case study carried out in this course.*	
7	***Course Conclusion***	**1**

Course Outcome: Learner will be able to

CO1: Identify and demonstrate the importance of research process in science and technology domains
CO2: Perform literature reviews using print and online databases.
CO3: Analyse the data using qualitative and quantitative methods
CO4: Identify and prepare the key elements of a research report/ paper
CO5: Illustrate the rationale for research and publication ethics

Text Books:

1. C. R. Kothari and Gaurav Garg, Research Methodology: Methods and Techniques, New Age International Publisher, 2014.
2. Ranjit Kumar, Research Methodology: A Step-by-Step Guide for Beginners, Sage Publication, 2018
3. R. Pannershelvam, Research Methodology, Prentice Hall, India, 2014

Reference Books:

1. John W. Creswel, Research Design: Qualitative, Quantitative, and Mixed Methods Approaches, 4th Ed., SAGE, 2018.Geoffrey R. Marczyk, David DeMatteo & David Festinger, Essentials of Research Design and Methodology, John Wiley & Sons, 2005.
2. Suresh C. Sinha and Anil K. Dhiman, Research Methodology (2 Vols-Set), Vedam Books, 2006.
3. Manfred Max Bergman, Mixed Methods Research, SAGE Books, 2006.
4. Paul S. Gray, John B. Williamson, David A. Karp, John R. Dalphin, The Research Imagination, Cambridge University press, 2007.
5. Cochrain & Cox, Experimental Designs, II Edn. Wiley Publishers, 2006

Other Resources:

NPTEL Course: Research Methodology By Prof. Edamana Prasad, Prof. Prathap Haridoss (IIT Madras) Weblink https://onlinecourses.nptel.ac.in/noc25_ge28/preview

Course Type	Course Code	Course Name	Credits
LLC	LLC6011	ART OF LIVING	02

Program Outcomes addressed:

1. PO6 : The Engineer & The World
2. PO7 : Ethics
3. PO8 : Individual and Team Work
4. PO9 : Communication
5. PO11: Life-long learning

Course Objectives :

1. To provide a comprehensive understanding of the principles of the Art of Living and their relevance to holistic well-being.
2. To equip participants with practical techniques like Sudarshan Kriya, yoga, and mindfulness for stress management and emotional balance
3. To enable participants to apply the Art of Living principles to enhance relationships, productivity, and life purpose.

Module	Details
01.	**Introduction to the Art of Living** Understanding the Mind and Stress, Breath and Life Energy, Basics of Yoga and Guided Meditation
02.	**Sudarshan Kriya and Breathing Techniques** Introduction to Sudarshan Kriya, Practicing Rhythmic Breathing Techniques
03.	**Emotional Well-being** Understanding and Balancing Emotions, Forgiveness and Gratitude Practices, Guided Meditation for Emotional Healing
04.	**Relationships and Social Connections** Compassion and Effective Communication, Stress-free Relationships, Group Activities for Trust and Collaboration
05.	**Living with Purpose and Awareness** Discovering Life Purpose, Mindfulness Practices, Time Management and Productivity
06.	**Sustaining the Practices** Developing a Daily Routine, Advanced Breathing Techniques, Reflections, and Closing Meditation
Total no. of hours: **30**	

Course Outcomes :

1. Gain insights into managing stress and emotions through breathwork and meditation

2. Develop skills for building harmonious relationships and enhancing emotional intelligence.
3. Cultivate mindfulness, compassion, and clarity in daily life.
4. Sustain the Art of Living practices for long-term well-being and self-discovery.

Text Books :

1. "Celebrating Silence" by Sri Sri Ravi Shankar (1999, Sri Sri Publications Trust)
2. "The Heart of Yoga: Developing a Personal Practice" by T.K.V. Desikachar (1995, Inner Traditions International)
3. "The Miracle of Mindfulness" by Thich Nhat Hanh (1975, Beacon Press)

Reference Books :

1. "Wisdom for the New Millennium" by Sri Sri Ravi Shankar (2000, Sri Sri Publications Trust)
2. "The Healing Power of the Breath" by Richard P. Brown and Patricia L. Gerbarg (2012, Shambhala Publications)

Course Type	Course Code	Course Name	Credits
LLC	LLC6012	Yoga and Meditation	02

Program Outcomes addressed:

1. PO6: The Engineer and The World
2. PO7: Ethics
3. PO11: Life-Long Learning

Course Objectives:

1. To raise awareness of the therapeutic and preventive benefits of Yoga and Meditation
2. To nurture Holistic wellness through the harmony of body, mind and self
3. To advocate for the application of Yogic science in the treatment and prevention of psychosomatic and Lifestyle disorders.
4. To inspire the practice of Yogic Science tools for fostering health and well-being in daily life.
5. To promote the art of purposeful and mindful living by cultivating a deep sense of oneness with the self, nature and the world.

MODULE	DETAILS
1.	**Introduction to Yoga and Meditation** Definition of Yoga, Importance of Yoga for Human life, Literature of Yoga: Yoga Sutra, Bhagavat Gita – Synthesis of Yoga, Hathapradipika etc. Challenges of health in students & youth - Studies, Yogic concept of Health and Meditation, Concept of Body and Disease in Yoga, Dimensions of Health- Physical, Mental, Social and Spiritual, Different types of yoga (Karma, Gyaan, Ashtanga, Bhakti), Eight limbs of ashtanga yoga.
2.	**Yoga and Wellness** Yoga and Medical perspectives – Health related fitness, Yoga for common ailments, Scientific Researches in Yoga, Yogic anatomy of Human body, Asanas – Definitions and classifications, Scientific reasoning behind the asanas, Yoga for Stress, Technostress and Lifestyle management. Mental Disturbances and Preventive, Curative Aspect of Yoga for Mental wellness.

3.	**Essentials of Yoga Practices** Difference between Yoga and Exercise, Obstacles in the path of Yogic Practices, Disciplines in Yogic practices – Prayers, Yama, Niyama, Place, Time, Diet, Schedule, Sequence for Yogic Practices. Yogasanas: Surya Namaskara, Standing asanas and Sitting asanas, Different groups of Yogasanas – Relaxation, Meditative, Digestive etc. Psycho-physiological effects and health benefits of Yogasana, Function and effect of Asanas - Digestive system, Respiratory system, Excretory system, Circulatory system, Nervous system etc.
4.	**Meditation – Role of Breath and Pranayama** Yogic anatomy, Wellness and Triguna system, Science of Pranayama – 'Prana', the vital principle, Prana and air element, Awareness - Breath Awareness, Different types of Breathing, Breath Control, Breath and Postures, Rhythmic Breathing, Pranic body in the five-fold body (Panchakosha), Power of breath, Difference between Pranayama and breathing, Prana and nervous system, Fivefold function of prana, Benefits of pranayama
5.	**Fundamental aspects of Meditation** Pranayama and deep breathing - Concept of Inhalation (Puraka), Retention (Kumbhaka), & Exhalation (Rechaka); Important Pranayamas; Pranayama and Meditation; Mind and Meditation; Inner Instrument – Mind, Constituents of Mind - Mana, Buddhi, Ahankar and Chitta(Consciousness), Magnitude of Mind, Buddhi – the determinative faculty; Body-Mind complex; Mind Cleansing; Yogic Meditation and Mindfulness meditations; Yogic Process and Outcome of Meditation – Pratyahara, Dharana and Dhyana; Scientific studies on Meditation and Healing.
6.	**Meditation Tools and Techniques** Why Meditate - States of Mind, Mind over Body – Processing Thoughts, Preparing for Meditation – Posture, Shanti prayers, Pranayama, Training the Mind: Practicing tools- Bhramari Pranayama, Sacred Pranav (Om) mantra, Mantra Japa/ajapa, Types of Mindfulness Meditations, Yoga Nidra, Body scan meditation, etc. Benefits of Meditation

Course Outcomes:

1. Gain comprehensive insights about the necessity of yoga for daily life.
2. Obtain a simplified understanding of the impact of mindful breathing on health wellbeing.
3. Acquire knowledge of 'practice and principles' of simple awareness meditation for Mental wellness
4. Gain required knowledge to improve overall health and immune system
5. Practice simple asanas and meditation techniques to improve concentration, self-confidence and inner peace

Text Books:

1. Light on the Yoga Sutras of Patanjali by B.K. Iyengar (Publisher: Orient Longman Pvt. Ltd. Mumbai)
2. Pranayama - The Art & Science by Dr. Nagendra H R (Publisher: Swami Vivekananda Yoga Prakashan, Bangalore)
3. Yog – Its Philosophy and Practice by Swami Ramdev (Publisher: Divya Prakashan, Haridwar)

Recommended Books

1. Pranayama-Science of Breath by Gharote, M. (Publisher: The Lonavla Yoga Institute, India)
2. Svatmarama's HathaYogaPradeepika by Gyan Shankar Sahay (Publisher: Yogic Heritage, India)
3. Yoga for Health and Peace by Padamshree Sadashiv Nimbalkar (Publisher: Yoga Vidya Niketan, Mumbai)

Other Resources:

1. NPTEL Course: Yoga and Positive Psychology for Managing career and life by Prof. Ashish Pandey, IIT Bombay.
Weblink https://archive.nptel.ac.in/courses/110/101/110101165/

2. SWAYAM Course: Yoga for Concentration by By Dr H R Nagendra, Dr Manjunath N K and Dr Apar Avinash Saoji from Swami Vivekananda Yoga Anusandhana Samsthana, Bangalore.
Weblink: https://onlinecourses.swayam2.ac.in/aic23_ge05/preview

Course Type	Course Code	Course Name	Credits
LLC	LLC6013	Health and Wellness	02

Program Outcomes addressed:

1. PO6: The Engineer and The World
2. PO7: Ethics
3. PO11: Life-Long Learning

Course Objectives:

1. To advocate for the significance of Holistic wellness
2. To enhance all dimensions of wellness through the lens of scientific temper.
3. To foster integrative medicine through mindful lifestyle choices and guided practices
4. To promote the integration of scientific research with ancient wellness practices & techniques.

MODULE	DETAILS
1.	**Foundations of Health Well-being** Defining Health and Wellness, Dimensions of wellness Determinants of Health behavior, Health in everyday life Constitution of your body, Medical Anatomy of physical body Layers of your Body: Physical, Physiological, Psyche Yogic anatomy of Physiological and Psyche layers, Triguna system
2.	**Physical Wellbeing** Management of Ailments: Common, Acute, chronic Integrative medicines: Ayurveda, Naturopathy, Yoga etc. Preventive care for illness, Lifestyle, Dietary habits, Repair and Rejuvenation
3.	**Emotional Wellness** Types of Emotions, Symptoms of emotional wellness Studies on challenges of emotional wellness: Sleep, Stress, Resilience, eating habits, attention deficit, Digital fatigue, Communications etc. Emotions and physical wellness Understanding the trinity of senses, sense objects and emotions, Studies on breath regulation, Role of breath in emotions, Yogic methods to emotional wellness

4.	**Mental Wellness** What is Mental Wellness, Dimensions of mental Wellness Scientific studies on Mental disorder issues: Depression, anxiety, behavioural disorder, addiction, self-disconnection, suicidal thoughts etc. Mind-Body issues: Mental Wellness, Mental illness and Physical illness, Constitution of Mind – Manas, Buddhi, ahankara, Chitta, Consciousness Intelligence and Mental Wellness, Modifications of Mind Paths to Mental Wellness: Regulating Thoughts, Meditation tools and process - Pranayama, Pratyahara, Dharna, Dhyana, Mindfulness meditation, Chakra meditation, Sabdh(mantra) Meditation, spiritual engagements
5.	**Intellectual Wellness** Mind, Intelligence and Intellectual Wellness Aspects of Intellect, incapacitate Intellect, Examining Intellectual Wellness, Nurturing Intellectual Wellness
6.	**Spiritual Wellness** Yogic understanding of term 'spiritual' Relationship: Physical, Physiological, Psyche, Consciousness (Spiritual) Symptoms of spiritual wellness Studies on Spiritual wellness and Body Healing Practices for spiritual wellness: Prayers, Yoga and Meditation, spiritual engagements

Course Outcome: Learner will be able to

1. Gain a comprehensive understanding of Holistic Health
2. Acquire essential knowledge to regulate thoughts and behavior.
3. Apply holistic health tools for emotional stability and healthy mind
4. Develop proficiency in applying cognitive faculty for intellectual pursuits
5. Acquire holistic wisdom for attaining inner peace in daily life

Text Books

1. Nature Cure for All: Natural Remedies for Health Disorders (Publisher: Nisargopachar Gramsudhar Trust, Pune)

2. Towards the Wellness of Body, Mind and Self – Conference Proceedings Editor - Dr. Jayanti Chavan (Publisher: Institute of Science and Religion, Navi Mumbai)

3. Ayurveda & Panchakarma – The Science of Healing and Rejuvenation by Dr. Sunil V. Joshi (Publisher: Motilal Banarsidass Publishing House, Delhi)

Reference books

1. Dr R Nagarathna and Dr H R Nagendra: Yoga for Promotion of Positive Health (Publisher: SVYP, Bangalore)

2. Text book of Kriya Yoga – The Cosmic Engineering of Life in the light of Medical Science by Yogacharyya Dr. Chanchal Roy Devsharmman
(Publisher: Motilal Banarsidass Publishing House, Delhi)

3. Yog – Its Philosophy and Practice by Swami Ramdev
(Publisher: Divya Prakashan, Haridwar)

Other Resources:

1. NPTEL Course: Adolescent Health And Well-Being: A Holistic Approach by Dr. Sumana Samanta, Dr. Parmeshwar Satpathy, IIT Kharagpur.
Weblink https://nptel.ac.in/courses/127105236

2. NPTEL Course: The Science of Happiness and Wellbeing by By Prof. Priyadarshi Patnaik, Prof. Manas K. Mandal from IIT Kharagpur.
Weblink https://onlinecourses.nptel.ac.in/noc23_hs06/preview

Course Type	Course Code	Course Name	Credits
LLC	LLC6014	DIET AND NUTRITION	02

Program Outcomes addressed:

1. PO6 : The Engineer & Society
2. PO7 : Ethics
3. PO11: Life-long learning

Course Objectives :

1. To provide students with a comprehensive understanding of nutrition principles and their application in promoting optimal health.
2. To develop critical thinking skills to evaluate nutritional information and make informed decisions.
3. To apply knowledge of nutrition education and counselling to promote healthy nutrition practices in individuals and group.
4. To demonstrate an understanding of role of nutrition in disease prevention and management.

Module	Details
01.	**Nutrition for wellness -1** Introduction to nutrition, food pyramid, Macros: Carbohydrates, Protein and fats, Micros: Vitamins A C E K and D, Minerals-Calcium, Iron and Zinc Importance of hydration, signs and symptoms, stages of dehydration.
02.	**Nutrition wellness -2** Introduction to mindful eating, plate concept, understanding physical and emotional hunger, eating disorder-Anorexia nervosa, bulimia nervosa and binge eating.
03.	**Exercise and fitness** Introduction to exercise and its importance, types of exercise its classification, side effects of over exercising, Impact of sedentary lifestyle on body composition.
04.	**Sleep and relaxation** Flow of circadian rhythm, sleep cycle, stages of sleep, sides effects, sleeping disorder- sleep apnea, insomnia, sleep hygiene routine and foods inducing sleep
05.	**Managing stress** Introduction to stress, causes, effects of stress, management of stress, foods and adaptogenic foods for stress management.
06.	**The lifestyle flow** Morning/ wake up rituals, meal flow i.e in which order to eat, post meal flow, bedtime rituals – how should your last hour of the day look like
Total no. of hours: **30**	

Course Outcomes :

1. Understand the fundamentals of nutrition and its role in promoting wellness.
2. Apply mindful eating practices to manage physical and emotional hunger.
3. Assess the importance of exercise and its impact on health and fitness
4. Gain insights into sleep hygiene and manage sleep-related disorders.
5. Develop strategies for stress management using nutrition and adaptogenic foods.
6. Assess the importance of exercise and its impact on health and fitness

Text Books :

1. Nutrition and dietetics by C.S. shah: covers various aspects of nutrition, including nutrient metabolism, dietary planning and diet therapy.
2. Dietetics by B. Srilakshmi- covers aspects of dietetics including nutrition, food science and diet therapy.

Reference Books :

1. Nutrition science by B. Shrilakshmi: provides an overview of nutrition, nutrient metabolism and dietary patterns
2. Food science by B. Shrilakshmi covers food, including food composition, food processing and food safety.

Course Type	Course Code	Course Name	Credits
LLC	LLC6015	PERSONALITY DEVELOPMENT	02

Program Outcomes addressed:

1. PO6 : The Engineer & Society
2. PO7 : Ethics
3. PO11: Life-long learning

Course Objectives :

1. To enhance self-awareness and self-confidence in the students.
2. To develop effective communication, leadership, and interpersonal skills.
3. To equip students with stress management and time management techniques.
4. To foster teamwork, problem-solving, and decision-making abilities.
5. To prepare students for professional life through resume building, interview skills, and networking.
6. To instill a growth mindset and adaptability in personal and professional contexts.

Module	Details
01.	**Self-Awareness and Emotional Intelligence** Understanding personality traits and self-assessment, Importance of emotional intelligence (EI) in personal and professional success, Strategies to enhance EI and self-awareness.
02.	**Communication Skills** Fundamentals of verbal and non-verbal communication, Public speaking, presentation skills, and storytelling, Listening skills and constructive feedback.
03.	**Leadership and Teamwork** Understanding importance of self-confidence, leadership styles, and their applications, Building effective teams and managing conflicts, Developing collaboration and networking skills.
04.	**Stress and Time Management** Recognizing stressors and managing stress effectively, Prioritization and goal-setting techniques, Tools for efficient time management and productivity.
05.	**Professional Development** Importance of presentation skills, resume writing, cover letter, and LinkedIn optimization, Interview preparation: Mock interviews and common questions, Networking skills and professional etiquette
06.	**Personal Growth and Adaptability** Developing a growth mindset and embracing lifelong learning, Cultivating resilience and adaptability to change, Setting long-term personal and professional goals
Total no. of hours: **30**	

Course Outcomes : By the end of this course, students will be able to:

1. demonstrate increased self-awareness and emotional intelligence.
2. communicate effectively in professional and personal contexts.
3. exhibit leadership and teamwork skills in various scenarios.
4. manage time and stress efficiently to enhance productivity.
5. prepare a professional resume, excel in interviews, and network effectively.
6. develop resilience, adaptability, and a growth-oriented mind-set.

Text Books :

1. Daniel Goleman, Emotional Intelligence: Why It Can Matter More Than IQ / What Makes a Leader: Why Emotional Intelligence Matters
2. Stephen R. Covey, The 7 Habits of Highly Effective People: Powerful Lessons in Personal Change

Reference Books :

1. Dale Carnegie, How to Win Friends and Influence People.
2. Anthony Robbins, Awaken the Giant Within: How to Take Immediate Control of Your Mental, Emotional, Physical, and Financial Destiny!
3. David J. Schwartz, The Magic of Thinking Big.
4. Robin Sharma, The Monk who sold his Ferrari.
5. Dorie Clark, Reinventing You: Define Your Brand, Imagine Your Future.
6. Gangadhar Joshi, Campus to Corporate: Your Roadmap to Employability.

Other Resources :

1. Videos and TED Talks by Simon Sinek, Brené Brown, Malcolm Gladwell and other motivational speakers
2. Online courses on communication and leadership (e.g., Coursera, LinkedIn Learning, EdX).