Vidya Pratishthan's

Kamalnayan Bajaj Institute of Engineering and Technology, Baramati.

(An Autonomous Institute)

Faculty of Science and Technology

Board of Studies

Mechanical Engineering

Syllabus

Third Year B. Tech.
Mechanical Engineering

(Pattern 2024)

(w.e.f. AY: 2026-27)

Vidya Pratishthan's

Kamalnayan Bajaj Institute of Engineering and Technology, Baramati.

Vision

To achieve Academic Excellence through Persistent and Synergic Collaborations amongst all Stakeholders.

Mission

1. To ensure holistic development of students as lifelong learners and problem solvers through value-based quality education.
2. To motivate faculty to attain the state-of-the-art knowledge and wisdom in their domain and be a facilitator towards cocreation of knowledge.
3. To frame and deploy conducive and empowering policies for multifaceted growth of students, faculty and staff to make them contributors towards excellence.
4. To partner with industry for mutually beneficial relations to generate employable and deployable workforce.
5. To fulfill the aspirations of alumni, parents, society, region and nation at large by generating technically competent and contributing manpower.

Department of Mechanical Engineering,

VPKBIET Baramati

Vision

To inculcate learning culture in students and faculties to meet the current and future technological challenges of industry and society

Mission

1. To impart the students with fundamental knowledge of mechanical engineering.
2. To provide practical exposure by promoting students for training and internship in related industries.
3. Holistic development of the students by inculcating ethical and moral values towards the society and environment.
4. To develop association with premier educational institutions, industries and alumni for enhancement of faculty skill.

Vidya Pratishthan's
Kamalnayan Bajaj Institute of Engineering and Technology
Board of Studies: Mechanical Engineering
Syllabus: Third Year (B. Tech.) Mechanical Engineering
2024 Pattern w.e.f. AY: 2026-2027

SEMESTER-V

Course Type	Course Code	Course Name	Teaching Scheme			Examination Scheme and Marks							Credits			
			TH	PR	TUT	CAA	ISE	ESE	TW	PR	OR	Total	TH	PR	TUT	Total
PCC	ME24301TH	Manufacturing Technology	3	-	-	10	30	60	-	-	-	100	3	-	-	4
PCC	ME24301PR	Manufacturing Technology	-	2	-	-	-	-	-	-	30	30	-	1	-	
PCC	ME24302TH	Heat & Mass Transfer	3	-	-	10	30	60	-	-	-	100	3	-	-	4
PCC	ME24302PR	Heat & Mass Transfer	-	2	-	-	-	-	-	30	-	30	-	1	-	
PCC	ME24303TH	Design of Machine Elements	2	-	-	10	-	60	-	-	-	70	2	-	-	3
PCC	ME24303PR	Design of Machine Elements	-	2	-	-	-	-	30	-	-	30	-	1	-	
PEC	ME24304XTH	Programme Elective I Course	3	-	-	10	30	60	-	-	-	100	3	-	-	4
PEC	ME24304XPR	Programme Elective I Course	-	2	-	-	-	-	-	-	30	30	-	1	-	
VSEC	ME24305TH	Numerical & Statistical Method	1	-	-	40	-	-	-	-	-	40	1	-	-	2
VSEC	ME24305PR	Numerical & Statistical Method	-	2	-	-	-	-	-	30	-	30	-	1	-	
MDM	XXXXXXXTH	Multidisciplinary Minor	3	-	-	10	30	60	-	-	-	100	3	-	-	4
MDM	XXXXXXXPR	Multidisciplinary Minor	-	2	-	-	-	-	30	-	-	30	-	1	-	
AC	HS24301	Constitution of India	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total			15	12	-	90	120	300	60	60	60	690	15	6	-	21

List of Electives and Multi-Disciplinary Minor

Code	Programme Elective I Course	Code	MDM
ME24304A	Measurement & Metrology	**AI24053**	**Artificial Intelligence and Machine Learning**
ME24304B	Industrial Fluid Power	BS24053	Linear Algebra And Statistics
ME24304C	Energy Audit and Management		

Dr. S. C. Mahadik	Dr. M. S. Lande	Dr. S. M. Bhosle	Dr. A. M. Kolekar
Academic Coordinator	**Head of Department**	**Dean Academics**	**Controller of Examination**

VPKBIET BARAMATI Affiliated to S.P.P.U. Pune Id No. /PU/PN/Engg./152/2000 PUNE (MS.)

Dr. S. B. Lande

Principal

Principal
Vidya Pratishthan's
Kamalnayan Bajaj Institute of
Engineering & Technology, Baramati
Vidyanagari, Baramati-413133

Vidya Pratishthan's
Kamalnayan Bajaj Institute of Engineering and Technology
Board of Studies: Mechanical Engineering
Syllabus: Third Year (B. Tech.) Mechanical Engineering
2024 Pattern w.e.f. AY: 2026-2027

SEMESTER-VI																
Course Type	Course Code	Course Name	Teaching Scheme			Examination Scheme and Marks							Credits			
			TH	PR	TUT	CAA	ISE	ESE	TW	PR	OR	Total	TH	PR	TUT	Total
PCC	ME24311TH	Design of Transmission System	3	-	-	10	30	60	-	-	-	100	3	-	-	4
PCC	ME24311PR	Design of Transmission System	-	2	-	-	-	-	-	-	30	30	-	1	-	
PCC	ME24312TH	Mechatronics & Control	2	-	-	10	-	60	-	-	-	70	2	-	-	3
PCC	ME24312PR	Mechatronics & Control	-	2	-	-	-	-	-	30	-	30	-	1	-	
PEC	ME24313X TH	Programme Elective II Course	3	-	-	10	30	60	-	-	-	100	3	-	-	4
PEC	ME24313X PR	Programme Elective II Course	-	2	-	-	-	-	-	-	30	30	-	1	-	
PEC	ME24314X TH	Programme Elective III Course	3	-	-	10	30	60	-	-	-	100	3	-	-	4
PEC	ME24314X PR	Programme Elective III Course	-	2	-	-	-	-	-	-	30	30	-	1	-	
MDM	XXXXXXXTH	Multidisciplinary Minor	2	-	-	10	-	60	-	-	-	70	2	-	-	3
MDM	XXXXXXXPR	Multidisciplinary Minor	-	2	-	-	-	-	30	-	-	30	-	1	-	
OE	OE24XXX	Open Elective	3	-	-	10	30	60	-	-	-	100	3	-	-	3
AC	HS24311	Democracy, Election and Governance	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total			**16**	**10**	**-**	**60**	**120**	**360**	**30**	**30**	**90**	**690**	**16**	**5**	**-**	**21**

List of Electives, Multi-Disciplinary Minor and Open Elective

Code	Programme Elective II Course	Code	Programme Elective III Course
ME24313A	Turbo Machines	ME24314A	Industrial Engineering & Quality Control
ME24313B	Heating, Ventilation and Air-Conditioning	ME24314B	Finite Element Analysis
		ME24314C	Renewable Energy Technology
Code	**MDM**	**Code**	**OE**
ET24053	**Internet of Things**	**OE24003**	**Design Thinking**
AI24052	Fundamentals of Programming Language	OE24004	Supply Chain Management

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ME24301- MANUFACTURING TECHNOLOGY		
Teaching Scheme:	**Credits:04**	**Examination Scheme:**
TH: 03 Hrs. / Week	**Theory : 03** **Practical: 01**	**CAA: 10 Marks**
		In-Semester Exam: 30 Marks
PR: 02 Hrs. / Week		**End-Semester Exam: 60 Marks**
		OR Exam: 30 Marks

Prerequisites: Mechanics, Material science and Engineering Metallurgy.

Objectives:

1. UNDERSTAND different types of manufacturing processes.

2. KNOW about fundamentals of metal cutting process, tool wear and tool life.

3. To provide students with a comprehensive understanding of various non-traditional machining processes.

4. IMPART the knowledge of machining phenomenon like grinding, super finishing, etc.

5. UNDERSTAND the basic concepts, importance and functions of Jigs, Fixtures.

6. GENERATE CNC program for appropriate machining processes like turning and milling.

Course Outcomes:

On completion of the course, learner will be able to

CO1. SELECT Appropriate Manufacturing Techniques: Apply process selection criteria to optimize material usage, cost, and production time while ensuring product reliability.

CO2. UNDERSTAND metal cutting principles and mechanics of metal cutting and tool life.

CO3. UNDERSTAND the unconventional manufacturing methods employed for making products.

CO4. SELECT appropriate grinding wheels & demonstrate the various surface finishing processes.

CO5. SELECT appropriate jigs/fixtures and to draw the process plan for a given component.

CO6. GENERATE CNC program for Turning / Milling processes and generate tool path using CAM software

Course Contents

Unit-1: Manufacturing Processes and Classification	**[06 Hrs.]**
Additive, subtractive and shaping processes; Relative advantages and limitations; Interdependency of geometry, material and process; Effect on product quality and cost; Part design for manufacturability; Process selection criteria.	
Unit-2: Material Removal Processes	**[08 Hrs.]**
Introduction to metal cutting, Elements of machining process, Geometry of single-point cutting tool, Orthogonal and Oblique cutting processes, Chip formation, Types of chips, Chip thickness ratio, Process parameters and their effect on machining, chip breakers, Merchant's Circle of forces analysis – forces and energy calculations, power consumed – MRR Effect of Cutting variables on forces, Concepts of Machinability- Factors affecting machinability, Machinability Index, Tool Life, Tool life equation of Taylor, Tool wear and its types, Factors affecting on tool life.	
Unit-3: Unconventional Manufacturing Processes	**[06 Hrs.]**
Abrasive Jet Machining, Water Jet Machining; Ultrasonic Machining; Electrical Discharge Machining, Wire EDM; Electrochemical Machining; Laser Beam Machining, Plasma Arc Machining and Electron Beam Machining; Introduction to Micro and nano-manufacturing	
Unit-4: Grinding & Surface finishing	**[06 Hrs.]**
Types and Operations of grinding machines, Grinding wheel– Shapes, Designation and selection, Abrasives & classification, Bond & bonding, Grit, Grade & Structure of wheels, Types of grinding wheels, mounting of grinding wheels, Glazing and loading of wheels, Dressing and truing of wheels, Balancing of wheels, Diamond wheels. Super-finishing processes – Introduction to Honing, Lapping, Buffing and Burnishing. (Construction, working and controlling parameters)	
Unit-5: Jigs and Fixtures	**[08 Hrs.]**
Significance and purpose of jigs and fixtures and their functions in the manufacturing processes, Concept of degree of freedom, 3-2-1 principle of location. General guidelines to	

design jigs and fixtures, advantages of jigs and fixtures.

Jigs: Definition, Elements of jig with the types, Location guidelines, Principles of clamping, Principles of guiding, Channel jig, Template jig, Plate jig, Angle plate jig, Turn over jig, Box jig, Latch type jig.

Fixtures: Definition. Elements of fixtures, Location guidelines, Principles of clamping, Principles of setting element, turning fixture, welding fixture, Milling fixture, Assembly and Inspection fixtures.

Unit-6: CNC Programming	**[08 Hrs.]**

CNC Programming-CNC part programming adaptable to suitable controllers. Steps in developing CNC part program. CNC part programming for Lathe Machine – Threading & Grooving cycle (Canned cycle). CNC part programming for Milling Machine - Linear & circular interpolation, milling cutter, tool length compensation & cutter radius compensation. Pocketing, contouring & drilling, subroutine and Do loop using canned cycle.

Text Books:

1. A Text Book of Production Technology, P. C. Sharma, S.Chand Publications
2. A Text Book of Manufacturing Technology, R. K. Rajput, Laxmi Publications (p) LTD
3. A Text book of Manufacturing Technology, Metal Cutting and Machine Tools, P. N. Rao, Vol. 2, 2nd edition, Tata McGraw Hill Publishing Co. Ltd, New Delhi, 2002
4. Elements of Workshop Technology, Vol-II, S. K. Hajra Chaudhary, Media Promoters &Publications Pvt Ltd.
5. S. K. Sinha, CNC Programming using Fanuc Custom Macro B, McGraw-Hill Professional

Reference Books:

1. Theory of Metal Cutting, M. C. Shaw, 1st Edition, Oxford and I.B.H. publishing, 1994
2. Jigs & Fixtures, P.H. Joshi, Third edition, McGraw Hill, 2017
3. Production Technology Manufacturing Systems VOL-I & II, R. K. Jain, Khanna Publishers
4. Production Technology –HMT, Tata McGraw Hill publication
5. An Expert Process Planning System, Chang, T. C., Addison Wesley Longman, 1990
6. Process Planning- Design/Manufacture Interface, Scallan P, Butterworth-Heinemann, 2003
7. CNC Machines, B. S. Pabla, M. Adithan, New Age International, 2018
8. Manufacturing Science, Amitabh Ghosh and AshokKumar Mallik, Affiliated East-West Press, 2010

Online Resource:

https://www.mooc-list.com/tags/manufacturing

Web References (NPTEL)

1.https://onlinecourses.nptel.ac.in/noc22_me28/preview

2.https://nptel.ac.in/courses/112105127

3.nptel.ac.in/courses/112/107/112107078/

Guidelines for Activity (Any One)

1. Industry Case Studies – Analyze real-world applications of different manufacturing processes (e.g., automotive, aerospace).
2. Presentation on Manufacturing Innovations – Present new advancements such as Nano manufacturing or Hybrid manufacturing.
3. Prepare the report on Advance simulation practices used in multinational companies. (Referhttps://www.siemens.com/global/en/products/automation.html,etc)

Guidelines for Lab /TW Assessment

The learner shall complete the following activity as a Lab work /Term Work; (Perform minimum 8 Practical's out of 10)

1. Practical Demonstration of Additive Manufacturing technology (from modelling to printing). (Batch wise)

2. Demonstration of cutting tool geometry and nomenclature of the tools used in conventional and CNC machines.

3. Demonstration of any one Unconventional Machining Process.

4. Machining of a mechanical component using conventional machines as per requirement. (Manufacturing drawing with appropriate geometrical and dimensional tolerances, detailed process planning to be included.)

5. Demonstration of various types of jigs and fixtures, and a case study on design and use of Jigs & Fixture for any given component.

6. Preparing Online Calculator/Catalogue for selection of cutting parameters by using programming languages like C, Python etc.

7. Preparing CNC part program using G Codes and M Codes for Mechanical Components on

CNC lathe, Virtual simulation of the same component using CNC Simu Soft software and also generating the program using CAM Master software.

8. Machining of mechanical components using CNC machines Lathe.

9. Preparing CNC part program using G Codes and M Codes for Mechanical Components on CNC VMC, Virtual simulation of the same component using CNC Simu Soft software and also generating the program using CAM Master software.

10. Machining of mechanical components using CNC machines Mill/HMC/VMC.

11. Visit to an Industry which uses advanced manufacturing processes. (Compulsory)

ME24302- HEAT & MASS TRANSFER		
Teaching Scheme:	**Credits:04**	**Examination Scheme:**
TH: 03 Hrs./Week	**Theory : 03** **Practical: 01**	**CAA: - 10 Marks**
		In-Semester Exam: 30 Marks
PR : 02 Hrs./Week		**End-Semester Exam: 60 Marks**
		Practical Exam: 30 Marks

Prerequisites: First and Second Law of Thermodynamics, Fluid properties, Continuity equation, Differential and Integral Calculus, Ordinary differential and Partial Differential Equations, Numerical solution for Differential Equations.

Objectives:

1. To build a solid foundation in heat transfer, exposing students to the three basic modes namely conduction, convection and radiation.

2. To provide rigorous treatment of governing equations and solution procedures for the three modes, along with the solution of practical problems using empirical correlations.

3. To cover boiling and condensation heat transfer, and the analysis and design of heat exchangers.

Course Outcomes:

On completion of the course, learner will be able to

CO1. ANALYZE & APPLY the modes of heat transfer equations for one dimensional thermal system.

CO2. DESIGN a thermal system considering fins and & Unsteady heat conduction.

CO3. EVALUATE the heat transfer rate in natural and forced convection & validate with experimentation results.

CO4. INTERPRET heat transfer by radiation between objects with simple geometries, for black and grey surfaces.

CO5. DESIGN & ANALYSE heat exchangers and investigation of its performance.

CO6. ANALYZE boiling and condensation heat transfer and ANALYSE the rate of Mass Transfer using Fick's law of Diffusion.

Course Contents

Unit-1: Fundamentals and Steady State Heat Transfer	**[07 Hrs.]**
Three modes of heat transfer; Derivation of heat balance equation & 3-D heat conduction equation in Cartesian coordinates (with derivation) and its simplified equations. 3-D heat conduction equation in Cylindrical and spherical coordinates (No derivation). Thermal conductivity, thermal diffusivity, electrical analogy and Resistances (conduction resistance, Film/Convection resistance, Radiation resistance and Thermal Contact Resistance). Boundary and initial conditions (Temperature, Heat Flux, Convection and Radiation boundary conditions), Steady 1D solution for conduction heat transfer in Plane wall, Cylinder and Sphere. Critical insulation of thickness for cylinder and sphere. Heat conduction with heat generation in Plane wall, Cylinder and Sphere with different boundary conditions.	
Unit-2: Heat Transfer through Fins and Unsteady Heat Conduction	**[07 Hrs.]**
Heat transfer through Fins: Types of fins and its applications. Governing Equation for constant cross sectional area fins, Solution for infinitely long fin (with derivation), adequately long fin with insulated end tip and short fins (no derivation), Fin Efficiency & Effectiveness. Unsteady heat conduction: Lumped and Transient, Lumped system approximation, Validity and criteria of lumped system analysis, Biot and Fourier Number, Time Constant and Response of thermocouple. Use of Heisler Charts for plane wall, cylinder and sphere.	
Unit-3: Convection Heat Transfer	**[07 Hrs.]**
Basic equations; Boundary layers (Velocity and Thermal boundary layers) in External and internal flows, Forced and Free Convection. Forced convection: Physical significance of non-dimensional numbers (Reynolds, Prandtl Nusselt and Stanton Number). Empirical correlations for flat plate, pipe flow, and flow across cylinders, spheres. Natural convection: Physical significance of non-dimensional numbers (Grashoff, Prandtl, and	

Rayleigh Number). Other dimensionless parameters for forced and free convection heat transfer (Peclet and Graetz Number); Empirical correlations for free convection.

Estimating heat transfer rates in laminar and turbulent flow situations using appropriate correlations for free and forced convection.

Unit-4: Radiation Heat Transfer	**[06 Hrs.]**

Thermal Radiation, Interaction of radiation with materials; Definitions of radiative properties; Stefan Boltzmann's law; Planck's law, Wien's displacement law, Kirchhoff's law and Lamberts Cosine law.

Black and grey body radiation; Calculation of radiation heat transfer between surfaces using radiative properties; View factors and the radiosity method; Electrical analogy for radiation, Radiation shields, Numerical.

Unit-5: Heat Exchangers Design	**[07 Hrs.]**

Function, classification and configuration of heat exchangers; Analysis and Evaluation of log mean temperature difference (LMTD) for parallel and counter flow heat exchangers; LMTD correction factor for cross flow and multi pass heat exchangers.

Effectiveness-NTU method for parallel and counter flow heat exchangers. Design of Condensers and Boilers. Design and selection of heat exchangers. Heat Pipe, TEMA Standards.

Unit-6: Boiling and Condensation and Introduction to mass transfer	**[06 Hrs.]**

Boiling: Types of boiling (Pool and Flow boiling), Regimes of pool boiling, Critical heat flux. Condensation: Film wise condensation, Drop wise condensation (No Numerical treatment), Mass Transfer: Applications of mass transfer, Mixture composition, Phase diagram, Analogy between heat and mass transfer; Fick's Law of diffusion; Conservation of Species, Mass diffusion coefficient, The Mass Diffusion equation in Cartesian coordinates (with derivation). Cylindrical coordinates and Spherical coordinates (no derivation), Boundary and initial conditions. Simultaneous heat and mass transfer.

Text Books:

1. A. Bejan, "Heat Transfer," John Wiley, 1993.

2. J.P. Holman and S. Bhattacharyya, "Heat Transfer," McGraw Hill, 2017.

3. F.P. Incropera, and D.P. Dewitt, "Fundamentals of Heat and Mass Transfer," John Wiley, 2019.

4. Massoud Kaviany, “Principles of Heat Transfer,” John Wiley, 2002.

5. Yunus A Cengel, “Heat Transfer: A Practical Approach,” McGraw Hill, 2002.

Reference Books:

1. P.K. Nag, Heat & Mass Transfer, McGraw Hill Education Private Limited.

2. M.M. Rathod, Engineering Heat and Mass Transfer, Third Edition, Laxmi Publications, New Delhi.

3. V. M. Domkundwar, Heat Transfer, Dhanpat Rai & Co Ltd.

4. A.F. Mills, Basic Heat and Mass Transfer, Pearson.

5. S. P. Venkatesan, Heat Transfer, Ane Books Pvt. Ltd.

6. Holman, Fundamentals of Heat and Mass Transfer, McGraw Hill publication.

7. M. Thirumaleshwar, Fundamentals of Heat and Mass Transfer, Pearson Education India.

8. B.K. Dutta, Heat Transfer-Principles and Applications, PHI.

9. C.P. Kothandaraman, S. V. Subramanyam, Heat and Mass Transfer Data Book, New Academic Science.

10. Process heat Transfer, D. Q. Kern, Wiley Publication.

Web References (NPTEL)

Online Resources:

1. https://onlinecourses.nptel.ac.in/noc22_ch65/preview

2.https://www.youtube.com/watch?v=qa-PQOjS3zA&list=PL5F4F46C1983C6785

3.https://www.youtube.com/watch?v=J_zqQcncAu4&index=3&list=PLpCr5N2IS7Nmu22MOgDWOr0sSlIpUNUz3

4.https://www.youtube.com/watch?v=SNnd0f3xXlg&list=PLpCr5N2IS7Nmu22MOgDWOr0sSlIpUNUz3&index=11

5.https://www.youtube.com/watch?v=lnFjt30goiY&index=18&list=PLpCr5N2IS7Nmu22MOgDWOr0sSlIpUNUz3

Guidelines for Activity (Any 2)

1. Formulate and analyze a heat transfer problem involving any of the three modes of heat transfer.

2. Obtain exact solutions for the temperature variation using analytical methods where possible or employ approximate methods or empirical correlations to evaluate the rate of heat transfer.

3. Design heat exchangers and estimate the insulation needed to reduce heat losses where necessary.

Guidelines for Lab /TW Assessment

Guidelines for Laboratory Conduction

The student shall complete the following activity as a Term Work

Complete eight experiments and two assignments (Sr. no.10 to 13).

1. Determination of Thermal Conductivity of insulating powder.

2. Determination of Thermal Conductivity of metal rod.

3. Determination of local and average heat transfer coefficient in Natural Convection.

4. Determination of local and average heat transfer coefficient in Forced Convection.

5. Determination of temperature distribution, fin efficiency in Natural / Forced Convection.

6. Determination of Emissivity of a Test surface.

7. Determination of Stefan Boltzmann Constant.

8. Determination of heat transfer, overall heat transfer coefficient and effectiveness of Plate Heat Exchanger.

9. Study of Pool boiling phenomenon and determination of Critical Heat Flux (CHF).

10. Assignment to solve transient heat transfer problem using Heisler and Grober Charts.

11. Design of heat exchanger for any simple application using software.

12. Industrial visit to heat treatment industry/ heat exchanger manufacturing industry.

13. Demonstration of dropwise and film wise condensation.

14. Virtual laboratory: study of the performance of heat exchanger /study of variation of Thermal Conductivity.

Link for Virtual Lab: - https://www.vlab.co.in/

ME24303-DESIGN OF MACHINE ELEMENTS		
Teaching Scheme:	**Credits: 03**	**Examination Scheme:**
TH: 02 Hrs./Week **PR : 02 Hrs./Week**	**Theory : 02** **Practical: 01**	**CAA: 10 Marks** **End-Semester Exam: 60 Marks** **Termwork: 30 Marks**

Prerequisites:

The following concepts are essential to understand: Material elastic behavior, stress, strain, their relationship, failure modes, different theories of failure, and their applications. Additionally, it is important to comprehend the design cycle, and basis of design considerations such as strength, rigidity, manufacture, assembly and cost, standards, and codes. One should also be familiar with preferred sizes and series, tolerances, types of fits, construction of SMD and BMD, as well as roots of equations and interpolation rules.

Objectives:

1. UNDERSTAND the various design considerations, design procedures, and select materials for a specific application.

2. CALCULATE the stresses in machine components due to various types of loads and failure.

3. ANALYZE machine components subjected to variable loading for finite and infinite life.

4. DESIGN various machine components such as shafts, couplings, keys, screws, joints, springs.

Course Outcomes:

On completion of the course, the learner will be able to

CO1. DESIGN AND ANALYZE the cotter and knuckle Joints and components subjected to eccentric loading.

CO2. DESIGN shafts, keys, and couplings under static loading conditions.

CO3. EVALUATE dimensions of machine components under fluctuating loads.

CO4. APPLY the design and development procedure for different types of springs.

Course Contents

Unit-1: Design of Simple Machine Components	**[06 Hrs.]**
The meaning of the design, engineering design, phases of design, design considerations, stress-strain considerations, factor of safety, Service factor, Design of the Cotter & Knuckle joint, and	

Design of components subjected to eccentric loading, Levers and its types.

Unit-2: Design of Shafts, Keys and Couplings	**[06 Hrs.]**

Shaft design on the Strength basis, torsional rigidity basis and lateral rigidity basis, Design of shaft as per A.S.M.E. code., Types of keys and their design. Design of Flange Coupling and Bushed-Pin Flexible Coupling.

Unit-3: Design against Fluctuating loads	**[06 Hrs.]**

Stress concentration and its factors, Reduction of stress concentration factors, fluctuating stresses, fatigue failures, endurance limit, S-N curve, Notch sensitivity, Endurance limit, Endurance strength modifying factors, Soderberg, Gerber, Goodman Lines, Modified Goodman diagrams.

Unit-4: Design of Springs	**[06 Hrs.]**

Types and applications of springs, Stress and deflection equations for helical compression Springs, Design of helical springs, surge in spring, Design of Multi-leaf springs, Nipping of Leaf springs.

Text Books:

1. Bhandari V.B., Design of Machine Elements, Tata McGraw Hill Publication Co. Ltd.
2. Shigley J.E. and Mischke C.R., Mechanical Engineering Design, McGraw Hill Publication Co. Ltd.

Reference Books:

1. Spotts M.F. and Shoup T.E., Design of Machine Elements, Prentice Hall International.
2. Juvinal R.C., Fundamentals of Machine Components Design, John Wiley and Sons.
3. Black P.H. and O. Eugene Adams, Machine Design, McGraw Hill Book Co. Inc.
4. Willium C. Orthwein, Machine Components Design, West Publishing Co. and Jaico Publications House.
5. Hall A.S., Holowenko A.R. and Laughlin H.G, Theory and Problems of Machine Design, Schaum's Outline Series.
6. C. S. Sharma and Kamlesh Purohit, Design of Machine Elements, PHI Learning Pvt. Ltd.
7. D. K. Aggarwal & P. C. Sharma, Machine Design, S.K Kataria and Sons.

8. P. C. Gope, Machine Design: Fundamentals and Applications, PHI Learning Pvt. Ltd.
9. Design Data - P.S.G. College of Technology, Coimbatore.
10. K. Mahadevan, K. Balveera Reddy, Design Data Handbook for Mechanical Engineers, CBS Publishers.

Term Work

Term work shall consist of "TWO" design projects. Each project shall consist of two imperial-size sheets – one involving assembly drawing with a parts list and overall dimensions and the other involving detailed drawings of individual components. Manufacturing tolerances, surface finish symbols and geometric tolerances should be specified to make it a working drawing. Use software for analysis and design proficiently. A design report giving all necessary calculations of the design of components and assembly should be submitted in a separate file. The design project should be "Design of Machine Elements" comprising various Machine elements **(Design of Screw Jack / Design of Welded-Threaded Joints)**. Where necessary, the design data book shall be used to select materials and standardized components. The drawings of one project shall be completed using any design and drafting software.

Course Activity

The course activity shall be internally presented in the form of a PowerPoint presentation, by a group of three to five students. A printout of the PPT is to be submitted. The topics for the presentations are as follows.

1. Material Innovations in Machine Design
2. Automation and Robotics in Machine Design
3. Failure Analysis and Reliability Engineering
4. Energy Efficiency in Machine Element Design
5. Impact of Industry 4.0 on Machine Design
6. Sustainability in Machine Design
7. Wear and Corrosion Resistance in Harsh Environments
8. Vibration and Noise Control in Industrial Machinery
9. Human-Centered Design in Machine Elements
10. Standards and Regulations in Machine Element Design

ME24304A - MEASUREMENT & METROLOGY		
Teaching Scheme:	**Credits:04**	**Examination Scheme:**
TH: 03 Hrs/Week **PR : 02 Hrs/Week**	**Theory : 03** **Practical: 01**	**CAA: - 10 Marks** **In-Semester Exam: 30 Marks** **End-Semester Exam: 60 Marks** **Oral Exam: 30 Marks**

Prerequisites: Engineering Mathematics, Engineering Mechanics, Manufacturing Processes, Engineering Drawing and Tolerancing, Basic Physics.

Objectives:

1. Introduce principles of engineering measurements and metrology systems.
2. Understand measurement errors, calibration and uncertainty analysis.
3. Learn different dimensional measurement techniques and instruments.
4. Study limits, fits and tolerances used in manufacturing.
5. Understand surface roughness, form errors and geometric tolerances.
6. Introduce modern metrology tools such as CMM, laser interferometry and machine vision systems.

Course Outcomes:

The students will be able to learn:

CO1 – Understand fundamentals of measurement systems.

CO2 – Analyze measurement errors and uncertainty.

CO3 – Use precision instruments for dimensional measurement.

CO4 – Apply limits, fits and tolerances in manufacturing design.

CO5 – Evaluate surface finish and geometrical errors.

CO6 – Understand modern metrology tools used in advanced manufacturing.

Course Contents

Unit- 1 Fundamentals of Measurement and Metrology	**[06 Hrs.]**

Definition of Measurement and Metrology, Measurement system components, Primary, Secondary and Tertiary standards, Types of measurements - Direct measurement, Indirect measurement, Static characteristics of measuring instruments - Accuracy, Precision, Sensitivity, Resolution, Linearity, Dynamic characteristics- Speed of response, Fidelity, Lag, Calibration procedures, Traceability. Simple Numerical on measurement.

Unit- 2 Measurement Errors and Uncertainty Analysis	**[06 Hrs.]**

Types of measurement errors- Systematic errors, Random errors, Gross errors, Sources of errors, error propagation, Statistical analysis of measurement data - Mean, Standard deviation, Variance, Confidence intervals, Uncertainty in measurements, Least squares method, Repeatability and reproducibility. Numericals on statistical analysis.

Unit- 3 Linear and Angular Measurements	**[06 Hrs.]**

Linear measurement instruments: Vernier caliper, Micrometer, Slip gauges (Gauge blocks), Dial indicators, Comparators- Mechanical, Optical, Electrical, Pneumatic, Angular measurements: Bevel protractor, Sine bar, Angle gauges, Autocollimator, Tool maker microscope. Numericals on slip gauges and sine bar.

Unit - 4 Limits, Fits and Tolerances	**[06 Hrs.]**

Concept of interchangeability, Types of tolerances - Unilateral, Bilateral, Fits - Clearance fit, Interference fit, Transition fit, ISO system of limits and fits, Hole basis system, Shaft basis system, Basic size, upper deviation and lower deviation, Allowance, Tolerance grades (IT grades), Gauge design - GO gauge, NO-GO gauge, Taylor's principle. Simple numericals on design of GO and NO- GO Gauges.

Unit -5 Thread and Gear Metrology, Surface Roughness Measurement	**[08 Hrs.]**

Measurement of Thread form: Thread form errors, Measurement of Minor, Major and Effective diameter (Three Wire Method), Flank angle and Pitch, Floating Carriage Micrometer (Numerical). **Gear Metrology**: Errors in Spur Gear form, Gear tooth Vernier, Constant chord, Base tangent (Numerical), Gear Rolling Tester. Profile Projector, Tool maker's microscope and their applications. **Surface Roughness Measurement**: Introduction to Surface texture, Parameters for measuring surface roughness, Surface roughness measuring instrument: TalySurf.

Unit - 6 Advanced Metrology and Modern Measurement Systems	**[06 Hrs.]**

Coordinate metrology- Coordinate Measuring Machine (CMM), Structure and working of CMM, Types of CMM, Optical metrology - Laser interferometry, Optical flats, Modern measurement techniques - Machine vision systems, 3D scanning, Digital metrology, Nano-metrology, Measurement Applications in Smart Manufacturing.

Text Books:

1. **Engineering Metrology** – K.J. Hume
2. **Engineering Metrology** – I.C. Gupta
3. **A Textbook of Metrology** - M. Mahajan

Reference Books :

1. **Engineering Metrology** - H.K. Jain
2. **Engineering Metrology and Instrumentation** – N.V. Raghavendra
3. **Mechanical Engineering Metrology** - M. Adithan
4. **Engineering Metrology and Measurements** – N.V. Raghavendra & L. Krishnamurthy

Web References (NPTEL):

1. nptel.ac.in/courses/112106179

2. https://www.youtube.com/watch?v=8DTt-f6wQxE&list=PL41FA714195562989

3. https://www.youtube.com/watch?v=3nio_KKMbnU

Guidelines for Activity

1. Unit-wise Assignments compulsory.
2. Design of Go–No Go gauges. (Any 5 Designs)
3. Case Study on Advanced Metrology and Modern Measurement Systems (1 Case Study).

OR

4. NPTEL Certification course on Measurement and Metrology.
5. Industry Visit to provide exposure to Advanced Metrology and Modern Measurement Systems.

Guidelines for Lab /TW Assessment: (Any Eight Experiments)

1. Linear Measurement: Demonstration and calculations using Vernier Caliper, Screw gauge, Dial gauge, height gauge.
2. Measurement of angle using Sine bar / bevel protractor.
3. Calibration of Pressure gauge by using Dead weight Tester.
4. To study calibration of linear variable differential transformers (LVDT).
5. Design of GO and NO-GO Gauges for the Mechanical Components.
6. Surface roughness measurement of a given sample using Tally Surf. Students should also plot a flow chart of its usage. (Virtual Lab).
7. Measurement of Screw threads Parameters using two wire or Three-wire methods.
8. Determination of geometry and dimensions of given composite object by using Optical Projector.
9. Verification of dimensions and geometry of given components using Mechanical comparator in context of manufacturing.
10. Measurement of gear tooth profile using gear tooth vernier /Gear tooth micrometer.
11. Determination of geometry of a given sample by using Coordinate Measuring Machine (CMM).

Guidelines for Lab /TW Assessment:

PR: Practical Performance or Oral exam will be conducted to evaluate Practical's.

ME24304B-INDUSTRIAL FLUID POWER		
Teaching Scheme:	**Credits: 04**	**Examination Scheme:**
TH: 03 Hrs./Week **PR : 02 Hrs./Week**	**Theory : 03** **Practical: 01**	**CAA: 10 Marks** **In-Semester Exam: 30 Marks** **End-Semester Exam: 60 Marks** **OR Exam: 30 Marks**

Prerequisites: Fluid Mechanics.

Objectives:

1. To understand the fundamentals of fluid power systems.
2. To study the construction, working principles, and characteristics of hydraulic components.
3. To analyze the operation and applications of hydraulic control valves and associated accessories in fluid power systems.
4. To develop hydraulic circuits for industrial applications using appropriate control elements.
5. To understand pneumatic systems and air preparation units.
6. To apply PLC-based control, system design principles, and maintenance practices in hydraulic and pneumatic systems.

Course Outcomes:

After completion of the course the students will be able to:

CO1: Explain the fundamental principles of fluid power systems and interpret standard hydraulic and pneumatic symbols.

CO2: Describe the working, construction, and performance characteristics of hydraulic fluids, pumps, and actuators.

CO3: Analyze the construction, working, and applications of directional, pressure, and flow control valves along with hydraulic accessories in fluid power systems.

CO4: Develop and analyze hydraulic circuits for industrial applications using appropriate control elements.

CO5: Explain the components, working principles, and circuit design of pneumatic systems used in industrial automation.

CO6: Design electro-hydraulic and electro-pneumatic systems using PLC-based control and apply maintenance and troubleshooting techniques.

Course Contents

Unit-1: Introduction to Fluid Power Systems	**[07 Hrs.]**
Overview of fluid power systems, Pascal' law & its applications, Advantages and disadvantages of hydraulic and pneumatic systems, Comparison between hydraulics and pneumatics, Basic components used in Hydraulic and Pneumatic systems, Applications in various industries, Symbols used in fluid power systems (ISO standard).	
Unit-2: Hydraulic Fluids, Pumps, and Actuators	**[06 Hrs.]**
Types and properties of hydraulic fluids, Selection criteria and contamination control, Hydraulic pumps: Gear, Vane, Piston, and Screw pumps, Hydraulic actuators: Linear (cylinders) and Rotary (motors), Performance characteristics and efficiency considerations.	
Unit-3: Hydraulic Control Systems and Circuits	**[06 Hrs.]**
Directional control valves, Pressure control valves, Flow control valves and Proportional Valves, Types and working principles of valves, Power units and accessories, Hydraulic accumulators and intensifiers, Pipes, hoses, fittings, sealing materials, Filters and strainers. Hydraulic Circuits: Simple reciprocating circuit, Regenerative circuit, Speed control circuits (meter-in, meter-out, bleed-off), Sequencing circuit, Synchronization circuit	
Unit-4: PLC and Electro-Fluid Power Control	**[06 Hrs.]**
Introduction to Programmable Logic Controllers (PLC), Basic architecture and working of PLC, Input-output modules and interfacing with hydraulic and pneumatic systems. Ladder logic programming fundamentals, Basic ladder programs (AND, OR, Timer, Counter). PLC-based control of hydraulic and pneumatic circuits, Electro-hydraulic and electro-pneumatic systems using solenoid-operated valves and relays.	

Unit-5: Pneumatic Systems and Components	**[07 Hrs.]**
Properties of compressed air and air preparation units, Pneumatic compressors, reservoirs, lubricators, mufflers and dryers, FRL Unit, Pneumatic actuators: Cylinders and motors, Directional, Pressure, and Flow control valves in pneumatics, shuttle valve, two pressure valve, quick exhaust valve and time delay valves, Pneumatic circuits and applications, Case studies of automated industrial applications.	
Unit-6: System Design, Maintenance, and Troubleshooting	**[06 Hrs.]**
Design considerations for hydraulic and pneumatic circuits, Design of hydraulic/pneumatic circuits for practical application, selection of different components such as reservoir, control elements, actuators, accumulator, intensifier, filters, pumps. Troubleshooting of fluid power systems, Preventive and predictive maintenance strategies, Energy efficiency and safety considerations in fluid power systems, Future trends in fluid power technology.	

Text Books:

1. Anthony Esposito, Fluid Power with Applications, 7th Edition, Pearson Education, 2008. ISBN-13: 978-0135136904.
2. Andrew Parr, Hydraulics and Pneumatics: A Technician's and Engineer's Guide, 3rd Edition, Butterworth-Heinemann, 2011. ISBN-13: 978-0080966748.
3. S.R. Majumdar, Oil Hydraulic Systems: Principles and Maintenance, Tata McGraw-Hill.
4. S.R. Majumdar, Pneumatic Systems: Principles and Maintenance, Tata McGraw-Hill.

Reference Books:

1. Jagadeesha T, Hydraulics and Pneumatics: A Practical Approach, I.K. International Publishing.
2. Joji P, Pneumatic Controls, Wiley India.
3. ILANGO S, Introduction to Hydraulics and Pneumatics, PHI Learning.
4. R. S. Khurmi, A Textbook of Hydraulics, Fluid Mechanics and Hydraulic Machines, S. Chand.

Web References:

1. **https://www.ifps.org – International Fluid Power Society**
2. **https://www.hydraulicspneumatics.com**
3. **https://www.automation.com – Industrial automation resources**
4. **https://nptel.ac.in – NPTEL courses on Hydraulics and Automation**

5. **https://www.parker.com – Parker Hannifin Fluid Power Technology Resources**
6. **https://www.boschrexroth.com – Industrial hydraulics learning material**
7. **https://www.festo-didactic.com – Pneumatics and automation training resources**
8. **https://www.machinedesign.com – Articles on fluid power systems**
9. **https://www.powermotiontech.com – Fluid power engineering portal**

List of Experiments (All Compulsory)

1.Study of basic components used in Hydraulic and Pneumatic systems, symbols and standards.

2. Demonstration of hydraulic and pneumatic components.

3. Performance evaluation of hydraulic pumps.

4. Speed control of a hydraulic actuator using a flow control valve.

5. Simulation of basic hydraulic circuits using Automation Studio or any other similar software.

6. Simulation of basic pneumatic circuits using Automation Studio or any other similar software.

7. Implementation of electrohydraulic or electro-pneumatic control using solenoid-operated valves.

8. PLC programming for simple hydraulic and pneumatic applications.

9. Fault diagnosis and troubleshooting of hydraulic systems.

10. Preventive maintenance of hydraulic and pneumatic components.

Activities (Any One):

1.Group project on designing an automated fluid power system.
2.Hands-on workshop/training on PLC integration with fluid power systems.
3. Seminars/Powerpoint presentations on emerging trends in fluid power automation.
4. Online certification course on fluid power technology (optional).
5. Industrial visit to a hydraulic or pneumatic-based manufacturing facility.

ME24304C - ENERGY AUDIT & MANAGEMENT		
Teaching Scheme:	**Credits: 04**	**Examination Scheme:**
TH: 03 Hrs./Week **PR : 02 Hrs./Week**	**Theory : 03** **Practical: 01**	**CAA: 10 Marks** **In-Semester Exam: 30 Marks** **End-Semester Exam: 60 Marks** **OR Exam: 30 Marks**

Prerequisites:

Engineering Thermodynamics, Applied Thermodynamics, Heat and Mass Transfer, HVAC Systems, Turbomachinery.

Objectives:

1. To familiarize students with energy demand patterns, conservation principles and energy management practices in industrial and commercial sectors.

2. To develop the ability to evaluate energy consumption and identify improvement opportunities through energy auditing techniques.

3. To enable students to analyse energy performance of thermal and electrical systems and recommend suitable energy conservation measures.

Course Outcomes:

After completion of the course the students will be able to:

CO1: Describe global and national energy scenarios and the significance of systematic energy management.

CO2: Perform structured energy audits for institutions, industries, or organisations.

CO3: Evaluate the economic feasibility of energy conservation measures using financial analysis tools.

CO4: Examine the energy performance of thermal utility systems and identify improvement possibilities.

CO5: Analyze electrical energy utilisation systems and propose methods for energy savings.

CO6: Explain energy performance enhancement using cogeneration and waste heat recovery technologies.

Course Contents

Unit-1: Energy Scenario and Energy Management	**[06 Hrs.]**
Overview of energy demand in developing economies, Present and future energy outlook in India and worldwide, Energy conservation and efficient utilization of energy resources, Interaction between energy use and environmental concerns, Importance of renewable and sustainable energy sources, Fundamental principles of energy management systems, Energy policies, planning strategies and implementation frameworks, Energy security, reliability, and recent reforms in the energy sector.	
Unit-2: Energy Audit	**[06 Hrs.]**
Role and importance of energy auditing in industries and institutions, Different classifications of energy audits, Systematic procedure for conducting an energy audit, Instrumentation and measurement techniques used during audits, Interpretation of collected data and formulation of recommendations, Benchmarking and performance indicators, Preparation of professional energy audit reports, Overview of software tools and simulation approaches used in energy studies, Important provisions of the Energy Conservation Act and Electricity Act.	
Unit-3: Energy Economics	**[06 Hrs.]**
Economic evaluation of energy utilities (Numerical): Estimation of cost of steam, fuel, compressed air, and electricity, financial appraisal methods for energy conservation projects (Numerical): Payback period, Time value of money, Net Present Value (NPV), Return on Investment (ROI), Internal Rate of Return (IRR).	
Unit-4: Assessment of Thermal Utilities	**[06 Hrs.]**
Performance evaluation and energy saving possibilities in: Boilers and furnaces (Direct efficiency method – numerical), Heat exchangers, Cooling towers, Diesel generator sets, Fans and blowers, Pumps, Compressors, Compressed air networks, HVAC installations Analysis of steam distribution system including: Steam line losses, Steam leakage detection, Steam traps, Condensate recovery, Flash steam utilization.	
Unit-5: Assessment of Electrical Utilities	**[06 Hrs.]**

Structure of electricity tariffs and billing components, Load management strategies and control of maximum demand, Penalties related to electrical consumption, Power factor correction methods and capacitor selection, Losses in electrical distribution systems and transformers, Harmonics, and their impact on power quality.

Electrical motors: Types and operating characteristics, Efficiency evaluation, Selection criteria, Speed control techniques, Energy efficient motor technologies, Lighting systems:

Types of lamps and their characteristics, recommended illumination standards, Lighting performance analysis (Numerical), Energy conservation measures in lighting.

Unit-6: Cogeneration and Waste Heat Recovery	**[06 Hrs.]**

Concept and significance of combined heat and power (CHP) systems, Advantages and industrial applications of cogeneration, Classification of cogeneration technologies, Introduction to trigeneration systems.

Waste Heat Recovery (WHR): Types of waste heat sources, Industrial applications of WHR, Introduction to pinch analysis, Potential for heat recovery in industrial processes, Commercial WHR equipment and devices.

Basic concepts of carbon credits and clean development mechanisms (CDM).

Text Books:

1. Bureau of Energy Efficiency Study material for Energy Managers and Auditors Examination: Paper I to IV.

Reference Books:

1. Barney L. Capehart, Wayne C. Turner and William J. Kennedy, “Guide to Energy Management”, Seventh Edition, The Fairmont Press Inc., 2012.

2. Craig B. Smith, “Energy Management Principles”, Pergamon Press, 2015.

3. Hamies, “Energy Auditing and Conservation; Methods, Measurements, Management and Case Study”, Hemisphere Publishers, Washington, 1980.

4. Albert Thumann P.E. CEM, William J. Younger CEM, “Handbook of Energy Audit”, The Fairmont Press Inc., 7th Edition.

5. Wayne C. Turner, "Energy Management Handbook", The Fairmont Press Inc., , Georgia.

6. Abbi Y. A., Jain Shashank, "Handbook on Energy Audit and Environment management", TERI, Press, New Delhi, 2006.

7. Anthony L Kohan, "Boiler Operator's Guide", Fourth Edition, McGraw Hill

8. Robert L. Loftness, "Energy Hand Book", Second edition, Von Nostrand Reinhold Company

9. G. G. Rajan, "Optimizing Energy Efficiencies in Industry", Tata McGraw Hill, 2001

10. Amlan Chakrabarti, "Energy Engineering and Management", Prentice Hall, India 2011

Web References:

1. NPC
2. BUREAU OF ENERGY EFFICIENCY, Government of India, Ministry of Power
3. Energy Conservation Guidelines published by BEE.
4. https://onlinecourses.nptel.ac.in/noc26_hs115/course (NPTEL Course)

List of Practical / Laboratory Experiments (Minimum 08)

Students will perform the following activities:

1. Study and analysis of energy audit methodology.
2. Evaluation of energy consumption pattern of institutional buildings.
3. Analysis of lighting system efficiency using illumination standards.
4. Case study on boiler performance assessment.
5. Analytical study of pump and compressor efficiency.
6. Evaluation of HVAC energy performance.
7. Study of power factor correction and electrical load management.
8. Estimation of utility costs using energy economics methods.
9. Study of waste heat recovery opportunities in industries.
10. Preparation of a mini energy audit report of the Home/Institute/Department.

Activities:

Evaluation based on (Any One):

2. Assignments
3. Case study analysis
4. Tutorials/quizzes

ME24305- NUMERICAL & STATISTICAL METHOD		
Teaching Scheme:	**Credits:02**	**Examination Scheme:**
TH: 01 Hrs./Week **PR : 02 Hrs./Week**	**Theory : 01** **Practical: 01**	**CAA: 40 Marks** **Practical Exam: 30 Marks**

Prerequisites: Basic knowledge of engineering mathematics (algebra, calculus, matrices), basic statistics, and fundamental programming concepts.

Objectives:

After completion of this course, the student will be able to:

1. Understand the concept of numerical methods used to solve engineering problems where analytical solutions are difficult.
2. Develop computer programs to solve equations, differential equations, and systems of linear equations using numerical techniques.
3. Apply numerical methods for curve fitting, regression, and numerical integration for engineering data analysis.
4. Use computational tools (MATLAB/Python/C or similar software) to implement numerical algorithms efficiently.
5. Analyze engineering datasets using statistical and numerical techniques.
6. Develop problem-solving skills by implementing numerical methods for real mechanical engineering applications.

Course Outcomes:

On completion of the course, the learner will be able to:

CO1. Implement numerical algorithms to determine roots of nonlinear equations using appropriate numerical methods.

CO2. Solve systems of linear equations and differential equations using numerical techniques through computer programs.

CO3. Apply numerical integration methods to evaluate definite integrals arising in engineering problems.

CO4. Perform curve fitting and regression analysis for engineering datasets using suitable numerical methods.

CO5. Use inbuilt computational tools/functions to obtain solutions of numerical problems efficiently.

CO6. Develop and implement a mini project based on numerical methods to solve a mechanical engineering application problem.

Course Contents

Unit-1: Numerical Integration	**[03 Hrs.]**
Concept of numerical integration, Trapezoidal Rule, Simpson's 1/3 Rule, Applications of numerical integration in engineering problems.	
Unit-2: Partial Differential Equation	**[03 Hrs.]**
Finite difference method, Simple Laplace method, PDE's, Parabolic explicit solution, Elliptic explicit solution.	
Unit-3: Statistical Methods for Engineering Data	**[03 Hrs.]**
Descriptive statistics including mean, median, variance and standard deviation, probability concepts and distributions, hypothesis testing, correlation and regression analysis, statistical quality control, application of statistical methods in manufacturing and quality engineering.	
Unit-4: Applications of Data Science in Mechanical Engineering	**[03 Hrs.]**
Predictive maintenance of machines, smart manufacturing systems, production optimization using data analytics, fault detection in mechanical systems, energy consumption analysis in industries, quality inspection and defect detection, industrial case studies.	

Reference Books:

1. Steven C. Chapra, 'Applied Numerical Methods with MATLAB for Engineers and Scientist', Tata Mc-Graw Hill Publishing Co. Ltd.
2. B. S. Grewal, 'Numerical Methods in Engineering and Science', Khanna Publication.
3. Joe D. Hoffman, 'Numerical Methods for Engineers and Scientists', CRC Press.

Practical Syllabus

1. Computer program to find the root of an equation using: (i) Bisection Method (ii) Newton–Raphson Method
2. Computer program to find the solution of ordinary differential equations using: (i) Euler's Method (ii) Runge–Kutta Fourth Order Method
3. Computer program to find the solution of a partial differential equation using Laplace Equation.
4. Computer program to find the solution of linear simultaneous equations using: (i) Gauss Elimination Method (ii) Gauss–Seidel Method
5. Computer program on curve fitting using: (i) Least Square Technique - First Order (ii) Least Square Technique - Power Equation
6. Computer program to perform numerical integration using: (i) Trapezoidal Rule (ii) Simpson's 1/3 Rule
7. Computer programs using inbuilt functions for solving numerical methods problems related to: (i) Root of Equation (ii) Ordinary Differential Equations (iii) Linear Simultaneous Equations (iv) Curve Fitting (v) Numerical Integration
8. Statistical analysis of engineering data including calculation of mean, median, variance, standard deviation and correlation.
9. Time-series analysis of machine or process data such as temperature, vibration or production rate.

Guidelines for Conducting Practical Sessions:

1. Practicals shall be conducted in the Computer laboratory.
2. Software shall be used MATLAB / Python / Scilab / C Programming.

Course Activity

Any two of the following activity shall be conducted:

1. Development of a simple computer program to solve a mechanical engineering application problem using appropriate numerical methods and visualization of results.
2. **Data Visualization Activity:** Students will analyze a given mechanical or

manufacturing dataset and create interactive visualizations using tools such as Power BI, Tableau, or Excel dashboards.

3. **Industrial Data Analysis Case Study**: Students will study a real-world mechanical engineering dataset (machine performance, production data, or energy consumption) and interpret patterns using visualization tools.
4. NPTEL Course Certification recommended by Course Teacher.

AI24053- ARTIFICIAL INTELLIGENCE & MACHINE LEARNING		
Teaching Scheme:	**Credits:04**	**Examination Scheme:**
TH: 03 Hrs./Week **PR : 02 Hrs./Week**	**Theory: 03** **Practical: 01**	**CAA: - 10 Marks** **In-Semester Exam: 30 Marks** **End-Semester Exam: 60 Marks** **Termwork: 30 Marks**

Prerequisites: Basic knowledge of Programming (preferably Python), Engineering Mathematics (Linear Algebra, Probability & Statistics), and Data Structures.

Objectives:

- To **understand** the fundamental concepts of Natural Language Processing, Computer Vision, and Recommendation Systems.
- To **explain** the principles of reinforcement learning and its role in intelligent decision-making systems.
- To **analyze** real-world applications of AI in domains such as healthcare, finance, and smart systems.
- To **evaluate** ethical issues and societal impacts associated with Artificial Intelligence technologies.
- To **explore** emerging trends and future developments in Artificial Intelligence.

Course Outcomes:
The students will be able to learn:

CO1: Apply Python programming concepts and libraries such as NumPy, Pandas, and Matplotlib for data handling and visualization in AI/ML applications.
CO2: Analyze datasets using data pre-processing techniques and exploratory data analysis methods to prepare data for machine learning models.
CO3: Implement supervised machine learning algorithms for regression and classification problems.
CO4: Analyze data using unsupervised learning techniques such as clustering and dimensionality reduction.
CO5: Explain and apply neural network models and deep learning concepts for intelligent system development.
CO6: Evaluate real-world applications, ethical implications, and emerging trends of Artificial Intelligence and Machine Learning technologies.

Course Contents

Unit I: Python for AI and Machine Learning	**06 Hrs.**
Introduction to Python Programming; Python Environment Setup; Basic Syntax; Variables and Data Types; Operators; Control Structures (if, loops); Functions and Modules; Python Data Structures (Lists, Tuples, Dictionaries, Sets); File Handling; Introduction to NumPy, Pandas and Matplotlib; Data Handling and Visualization for AI/ML.	
Unit II: Data Preprocessing and Exploratory Data Analysis	**07 Hrs.**
Types of Data; Data Collection and Dataset Formats; Data Cleaning and Handling Missing Values; Data Transformation and Normalization; Feature Selection and Feature Engineering; Exploratory Data Analysis (EDA); Data Visualization Techniques; Training, Validation and Test Sets.	
Unit III: Supervised Learning Algorithms	**08 Hrs.**
Introduction to Supervised Learning; Regression Methods (Linear Regression, Polynomial Regression); Classification Methods (Logistic Regression, k-Nearest Neighbor, Decision Trees); Support Vector Machines; Model Training and Testing; Performance Evaluation Metrics (Accuracy, Precision, Recall, F1-score).	
Unit IV: Unsupervised Learning Techniques	**08 Hrs.**
Introduction to Unsupervised Learning; Clustering Techniques (K-Means Clustering, Hierarchical Clustering); Density-Based Clustering; Dimensionality Reduction Techniques; Principal Component Analysis (PCA); Applications of Unsupervised Learning.	
Unit V: Neural Networks and Deep Learning	**08 Hrs.**
Introduction to Artificial Neural Networks; Biological Neuron Model; Perceptron Model; Multilayer Perceptron; Activation Functions; Backpropagation Algorithm; Introduction to Deep Learning; Convolutional Neural Networks (CNN) Basics; Applications of Neural Networks.	
Unit VI: Applications of AI and Machine Learning	**06 Hrs.**
Natural Language Processing (NLP); Computer Vision Basics; Recommendation Systems; Reinforcement Learning Fundamentals; AI Applications in Healthcare, Finance and Smart Systems; Ethical Issues in AI; Future Trends in Artificial Intelligence.	
Text Books: 1) Deisenroth, M. P., Faisal, A. A., and Ong, C. S., Mathematics for Machine Learning, Cambridge University Press, 2020. 2) B. Joshi, Machine Learning and Artificial Intelligence, Springer, 2020. 3) Parag Kulkarni and Prachi Joshi, Artificial Intelligence – Building Intelligent Systems,	

PHI Learning Pvt. Ltd., New Delhi, ISBN: 978-81-203-5046-5, 2015.
4) Stuart Russell and Peter Norvig, Artificial Intelligence: A Modern Approach, Pearson Education, 3rd Edition, 2003.

Reference Books:

1) Solanki, Kumar and Nayyar, *Emerging Trends and Applications of Machine Learning*, IGI Global, 2018.
2) Mehryar Mohri, Afshin Rostamizadeh and Ameet Talwalkar, *Foundations of Machine Learning*, MIT Press, 2018.
3) Kaushik Kumar, Govind Zindani and J. Paulo Davim, *Artificial Intelligence in Mechanical and Industrial Engineering*, CRC Press, 2021.
4) Zsolt Nagy, *Artificial Intelligence and Machine Learning Fundamentals*, Apress, 2018.
5) Elaine Rich, Kevin Knight and Shivashankar B. Nair, *Artificial Intelligence*, McGraw-Hill Education (TMH).

Web References (NPTEL)

1) Introduction to Machine Learning – Prof. Balaraman Ravindran IIT Madras (https://nptel.ac.in/courses/106106139)
2) An Introduction to Artificial Intelligence Prof. Mausam– IIT Delhi (https://nptel.ac.in/courses/106102220?utm_source=chatgpt.com)
3) Machine Learning- Prof. Carl Gustaf Jansson (https://nptel.ac.in/courses/106106202?utm_source=chatgpt.com)

Guidelines for Activity

- Apply Artificial Intelligence and Machine Learning techniques to solve a simple real-world problem using Python and machine learning libraries.

Guidelines for Lab /TW Assessment

1) Write Python programs to demonstrate basic data types, control structures, functions, and data structures.
2) Perform numerical computations and matrix operations using **NumPy**.
3) Perform data manipulation and analysis on a dataset using **Pandas**.
4) Visualize data using **Matplotlib / Seaborn** (line chart, bar chart, histogram, scatter plot).

5) Perform **data preprocessing** including handling missing values, normalization, and feature selection.
6) Implement **Linear Regression** algorithm for predicting continuous values.
7) Implement **Logistic Regression** for classification problems.
8) Implement **k-Nearest Neighbor (k-NN)** algorithm for classification.
9) Implement **Decision Tree** classifier and evaluate model performance.
10) Implement **K-Means Clustering** for unsupervised learning.
11) Perform **Dimensionality Reduction using Principal Component Analysis (PCA)**.
12) Develop a **Mini AI/ML Project** using a real-world dataset and present the results.

ME24311- DESIGN OF TRANSMISSION SYSTEM		
Teaching Scheme:	**Credits: 04**	**Examination Scheme:**
TH: 03 Hrs./Week **PR : 02 Hrs./Week**	**Theory : 03** **Practical: 01**	**CAA: 10 Marks** **In-Semester Exam: 30 Marks** **End-Semester Exam: 60 Marks** **Oral Exam: 30 Marks**

Prerequisites: Classification of Gears, Gear Terminology, Terminology of Helical gear, Virtual, number of teeth. Classification, selection, and application of Belt, chain and rope drives.

Objectives:

1. Learn how to design and choose parts for transmission systems.

2. Understand that real engineering problems have multiple solutions.

3. Apply design skills to real industrial problems.

4. Work in teams, think critically, communicate, and plan projects.

5. Consider safety, ethics, laws, and society in design work.

6. Develop practical solutions for real-world problems.

Course Outcomes:

On completion of the course, the learner will be able to

CO1: Understand gear terminology, materials, and failures. Apply design principles to analyze spur gear strength.

CO2: Understand helical and bevel gears. Apply strength and wear analysis for design.

CO3: Understand worm gears, efficiency, and materials. Analyze strength and wear as per standards.

CO4: Select rolling and sliding bearings using manufacturer data. Evaluate load conditions and bearing life.

CO5: Design machine tool gearboxes with speed variations. Create ray and kinematic diagrams.

CO6: Understand clutches and brakes. Apply design principles for industrial applications.

Course Contents

Unit-1: Spur Gear	**[07 Hrs.]**
Representation of Gears, Gear Material Selection, Gear Failure Modes , Gear Design Considerations , Strength and Load Analysis in Spur Gears – Force analysis, beam strength (Lewis equation), and wear strength (Buckingham's equation). Factors Affecting Gear Performance, Gear Design Calculations. AGMA Approach and FEA in Gear Design.	
Unit-2: Helical and Bevel Gear	**[08 Hrs.]**
Helical Gears Force Analysis of Helical Gear, Beam Strength of Helical Gear , Wear Strength of Helical Gear - , Estimation of Effective Load ,Velocity Factor (Barth Factor) , Buckingham's Equation - Dynamic Load Calculation, Empirical Constants, and Their Significance. **Bevel Gears** Types of Bevel Gears , Virtual Number of Teeth, Force Analysis of Straight Bevel Gear, Direction and Resolution of Forces Design of Straight Bevel Gear-Beam Strength - Lewis Equation for Bevel Gears, Wear Strength - Wear Resistance Factors, Surface Hardness, and Material Impact, Estimation of Effective Load - Velocity Factor (Barth Factor), Buckingham's Equation.	
Unit-3: Worm and Worm wheel	**[06 Hrs.]**
Worm and Worm Gear Terminology and Proportions, Force Analysis of Worm Gear Drives - Components of Force in Worm Gears, Direction and Resolution of Forces. Friction in Worm Gears, Efficiency of Worm Gears - Factors Affecting Efficiency, Calculation of Efficiency in Worm Gear Drives. Worm and Worm Gear Material , Strength and Wear Ratings of Worm Gears, Bending Stress Factor, Speed Factor, Surface Stress Factor, Zone Factor (IS 1443-1974).Thermal Consideration in Worm Gear Drive	
Unit-4: Bearings	**[07 Hrs.]**
Sliding Contact Bearing - Basic Concept of Sliding Contact Bearings, Types of Sliding Contact , Importance in Lubrication. Petroff's Equation - Derivation. Sommerfeld Number - Meaning and Importance, Effect on Bearing Performance. Parameters of Bearing Design - Load Capacity, Role of Lubrication, Effect of Friction. **Rolling Contact Bearing**-Types of Rolling Contact	

Bearings and Selection, Static and Dynamic Load Carrying Capacities - Load Ratings, Impact of Load Type on Bearing Life. Stribeck's Equation, Performance. Equivalent Bearing Load, Calculation of Equivalent Load. Load-Life Relationship, Selection of Bearing Life - Expected Service Life, Operating Conditions, and Safety Factors. Selection of Rolling Contact Bearings from Manufacturer's Catalogue.

Unit-5: Design of M/C Tool Gear Box	**[07 Hrs.]**

Introduction to Machine Tool Gearboxes ,Classification of Machine Tool Gearboxes ,Basic Considerations in Design of Drives and Applications , Determination of Variable Speed Range ,Graphical Representation of Speed and Structure Diagram , Ray Diagram ,Selection of Optimum Ray Diagram , Kinematic/Gearing Diagram ,Deviation Diagram , Difference Between Numbers of Teeth of Successive Gears in a Change Gearbox - Gear Progression, Practical Considerations.

Unit-6:Clutches and Brakes	**[07 Hrs.]**

Clutches

Introduction to Clutches, Positive Clutches, Friction Clutches, Special Clutches. Clutch Materials, Positive Clutches - Types of Positive Clutches, Applications in Machinery. Friction Clutches, Single Plate and Multiple Plate Clutch, Cone Clutch, Centrifugal Clutch Application of Clutches.

Brakes

Introduction to Brakes, Types of Brakes, Brake Materials - Commonly Used Materials, Selection Criteria Based on Application. Design of Band Brake, External and Internal Shoe Brakes, Shoe Brakes, Design of Disc Brakes, Application of Brakes.

Text Books:

1. Shigley J.E. and Mischke C.R., Mechanical Engineering Design, McGraw Hill Publication Co. ltd.
2. Spotts M.F. and Shoup T.E., Design of Machine Elements, Prentice Hall International.
3. Bhandari V.B, Design of Machine Elements, Tata McGraw Hill Publication Co. Ltd.
4. Juvinal R.C, Fundamentals of Machine Components Design, John Wiley and Sons.

Reference Books:

1. Design Data - P.S.G. College of Technology, Coimbatore.

2. Vehicle Powertrain Systems by Behrooz Mashadi, David Crolla. A John Wiley & Sons, Ltd

3. Automobiles–Power trains and Automobiles–Dynamics by Crolla, David, A John Wiley &Sons, Ltd

4. Automotive Engineering Powertrain, Chassis System and Vehicle Body by David A Crolla, Elsevier B H New York, London, Oxford.

5. Lack P.H. and O. Eugene Adams, Machine Design, McGraw Hill Book Co. Inc.

6. Willium C. Orthwein, Machine Components Design, West Publishing Co. and Jaico Publications House.

7. P. Kannaiah, Design of Transmission systems||, SCIETCH Publications Pvt Ltd.

8. C.S. Sharma and Kamlesh Purohit, Design of Machine Elements, PHI Learning Pvt. Ltd.

9. D.K. Aggarwal& P.C. Sharma, Machine Design, S.K Kataria and Sons.

10. P. C. Gope, Machine Design: Fundamentals and Applications, PHI Learning Pvt. Ltd.

11. Bhandari, V. B. Machine Design data book, Tata McGraw Hill Publication Co. Ltd.

12. K. Mahadevan, K. Balveera Reddy, Design Data Handbook for Mechanical Engineers, CBS Publishers.

Term Work

Students shall complete the following activity as a Term Work;

The Submission shall consist of completing Two Design projects. The oral examination shall be based on the practical's undertaken during the semester.

Design Project 1 (Anyone)

1. Design of gearbox for windmill application or sluice gate. (Use AGMA approach)
2. Design of gearbox for building Elevator. (Use AGMA approach)
3. Design of gearbox for Hoist. (Use AGMA approach)
4. Design of gearbox for Worm gearbox for the Sugar Industry. (Use AGMA approach)
5. Design of a clutch system for an automobile
6. Design of brake system for automobile

Design Project 2(Anyone)

1. **Multi-Spindle Gearbox Design**
    - **3D Model & Layout** – Design a multi-spindle gearbox using 3D software with assembly drawings, part list, and dimensions on two A1 sheets.
    - **Component Drawings –** Provide detailed drawings of individual components with manufacturing tolerances, surface finish symbols, and geometric tolerances.

- **Design Calculations** – Submit a report with calculations for gears, shafts, bearings, and housing, referencing the design data book.
- **Documentation & Submission** – Include a design report with all necessary calculations and justifications for component selection.

2. **Selection of Bearings from the Manufacturing Catalog**
   - **Determine Requirements** – Identify load type (radial, axial, or combined), speed (RPM), space constraints, and environmental conditions.
   - **Choose Bearing Type** – Select ball bearings (moderate loads, high speeds), roller bearings (higher loads), or special bearings based on application needs.
   - **Estimate Bearing Life** – Calculate life in revolutions and convert to hours to ensure reliability.

Course Activity

Activity (Any Two)

1. Failure Analysis of Gear using FEA.

2. Stress Analysis of Gear Using 3D software.

3. Group Presentation on the following topic A. HEV Components and it's Sizing B. Gear Failure Analysis C. Properties & selection of sliding bearing materials D. Application of belt, rope, and chain drives and their selection method for Industry E. Transmission system of HEV.

4. MCQ Test on Units 1 to 6.

ME24312-Mechatronics & Control		
Teaching Scheme:	**Credits: 03**	**Examination Scheme:**
TH: 02 Hrs./Week **PR : 02 Hrs./Week**	**Theory : 02** **Practical: 01**	**CAA: 10 Marks** **End-Semester Exam: 60 Marks** **Practical Exam: 30 Marks**

Prerequisites: Engineering Mathematics, Basic Electrical/Electronic Engineering

Course Objectives:

1. To introduce the concept of mechatronics systems.
2. To study sensors, actuators, and signal conditioning components.
3. To understand fundamental control system principles and PLC-based automation in mechatronic systems.
4. To apply PID control techniques for analysis and design of mechatronic systems using simulation tools.

Course Outcomes:

After completion of the course the students will be able to:

CO1: Explain the concept of mechatronics systems and identify key components used in integrated engineering systems.

CO2: Describe the working principles and applications of sensors, actuators, and interface devices used in mechatronics.

CO3: Analyze basic control system concepts and implement PLC-based control for simple mechatronic systems.

CO4: Design and analyze PID control strategies for mechatronic systems using simulation tools.

Course Contents

Unit-1: Introduction to Mechatronics Systems	**[06 Hrs.]**
Definition and evolution of mechatronics, interdisciplinary nature of mechatronics systems,	

elements of a mechatronic system, block diagram representation, measurement systems and signal conditioning basics, open-loop and closed-loop systems, examples of mechatronic systems (CNC machine, washing machine, automobile systems etc).

Unit-2: Sensors and Actuators in Mechatronics	**[06 Hrs.]**

Classification of sensors, displacement sensors (LVDT, potentiometer), proximity sensors, temperature sensors, force and pressure sensors, signal conditioning basics.

Actuators used in mechatronic systems: DC motors, stepper motors, servo motors, solenoids, hydraulic and pneumatic actuators. Selection criteria and applications.

Unit-3: Fundamentals of Control Systems	**[06 Hrs.]**

Concept of feedback control systems, Modelling Electrical and Mechanical Systems, Block diagrams and it's reduction techniques, transfer functions.

Introduction to PLCs: Components and Operation, PLC Programming Basics: Ladder Logic and Function Blocks, Applications of PLCs in Control Systems.

Unit-4: PID Control and Applications	**[06 Hrs.]**

Detailed study of PID control: P, I, D control actions and their effects, PID controller tuning methods (basic introduction) Time response analysis of systems, Simulation of PID control using MATLAB/Simulink, Applications of PID in industrial control systems.

Text Books:

1. **W. Bolton**, *Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering*, Pearson.
2. **S.R. Deb**, *Robotics Technology and Flexible Automation*, McGraw Hill.
3. **Katsuhiko Ogata**, *Modern Control Engineering*, Prentice Hall.

Reference Books:

1. Nitaigour Mahalik, *Mechatronics Principles, Concepts and Applications*, McGraw Hill.

2. Robert H. Bishop, *The Mechatronics Handbook*, CRC Press.

3. John J. Craig, *Introduction to Robotics: Mechanics and Control*, Pearson.

4. Kuo & Golnaraghi, *Automatic Control Systems*, Wiley.

Web References:

1. **https://nptel.ac.in – NPTEL courses on Mechatronics, Robotics and Control**
2. **https://www.ifr.org – International Federation of Robotics**
3. **https://www.festo-didactic.com – Mechatronics and automation learning resources**
4. **https://www.mathworks.com – Control and robotics simulations**
5. **https://www.universal-robots.com – Industrial robot applications**
6. **https://ocw.mit.edu – Robotics and control courses**

Guidelines for Activity (Any one)

1. Case study and presentation on a real-life mechatronic system.
2. Simulation study of a basic control system using MATLAB/Simulink.
3. NPTEL or Similar certification in Mechatronics and/or Control System.
4. Seminar on emerging trends in mechatronics, automation technologies.

List of Experiments (Any 06)

1. Study of components of a mechatronic system using block diagram representation.
2. Study and characteristics of sensors used in mechatronic systems (LVDT, proximity sensor, temperature sensor-any one).
3. Simulation study of actuators (DC motor / stepper motor characteristics).
4. Simulation of open-loop and closed-loop control systems using MATLAB/Simulink.
5. Simulation of PID controller for a simple system.
6. Basic PLC Programming: Program and simulate basic PLC functions using ladder logic.
7. PLC-based control of a simple mechatronic system (e.g., motor ON-OFF control, sequence control).
8. Ladder logic programming involving Timers and Counters using suitable Simulation Software.

ME24313A- TURBO MACHINES		
Teaching Scheme:	**Credits: 04**	**Examination Scheme:**
TH: 03 Hrs./Week **PR : 02 Hrs./Week**	**Theory : 03** **Practical: 01**	**CAA: 10 Marks** **In-Semester Exam: 30 Marks** **End-Semester Exam: 60 Marks** **Oral Exam: 30 Marks**

Prerequisites: Objectives:

Engineering Mathematics, Engineering Thermodynamics, Fluid mechanics, Heat Transfer.

Course Objectives:

1. To introduce the fundamental concepts, classification, and working principles of turbo machines used in hydraulic and thermal systems.
2. To develop an understanding of the impulse–momentum principle and its application to jet impact on vanes used in turbo machinery.
3. To study the construction, working principles, and performance characteristics of hydraulic turbines used in hydroelectric power plants.
4. To familiarize students with analysis and operation of steam turbines used for power generation.
5. To understand the working principles, performance analysis, and operational characteristics of centrifugal pumps.
6. To study the construction, working principles, and performance characteristics of centrifugal and axial compressors used in energy systems.

Course Outcomes:

On completion of the course the learner will be able to;

CO1: DESCRIBE the classification, working principles, and applications of turbo machines including the impact of jet on vanes.

CO2: ANALYZE the working principles, velocity diagrams, and performance characteristics of impulse water turbines.

CO3: EXAMINE the constructional features and performance characteristics of reaction water turbines.

CO4: DETERMINE performance parameters of impulse and reaction steam turbine along with discussion of nozzles, governing mechanism & losses.

CO5: MEASURE performance parameters of single & multistage centrifugal pumps along with

discussion of cavitation and selection.

CO6: ILLUSTRATE the working principles and performance characteristics of centrifugal compressor along with discussion of theoretical aspects of axial compressor.

Course Contents

Unit-1: Introduction to Turbo Machinery	**[08 Hrs.]**
Turbo machines (Hydraulic & Thermal), Classification of Turbo machines, Comparison with positive displacement machines, Fundamental equation governing turbo machines, Different losses associated with turbo-machinery, Applications of Turbo machines. **Impact of Jet** Impulse momentum principle and its applications, Force exerted on fixed and moving flat plate, hinged plate, curved vanes, series of flat plates and radial vanes, velocity triangles and their analysis, work done equations, vane efficiency.	
Unit-2: Impulse Water Turbines	**[06 Hrs.]**
Introduction to Hydro power plant, classification of hydraulic turbines construction, principle of working, velocity diagrams and analysis, design aspects, performance parameters, performance characteristics, specific speed, selection of turbines, multi-jet Pelton wheel.	
Unit-3: Reaction Water Turbines	**[08 Hrs.]**
Classifications, Francis, Propeller, Kaplan Turbines, construction features, velocity diagrams and analysis, degree of reaction, performance characteristics. Draft tubes: types and analysis, causes and remedies for cavitation phenomenon Governing of turbines, Similitude and dimensional analysis of hydraulic turbines	
Unit-4: Steam Turbines	**[08 Hrs.]**
Steam nozzles: types and applications, Equation for velocity and mass flow rate [No numerical treatment]. **Steam Turbines:** Classifications, construction details, compounding of steam turbines, velocity diagrams and analysis of Impulse and reaction turbines (single & multi stage), governing, dimensional analysis, performance characteristics. Losses in steam turbines, selection of turbines.	

Unit-5: Centrifugal Pumps	**[08 Hrs.]**
Classification of rotodynamic pumps, components of centrifugal pump, types of heads, velocity triangles and their analysis, effect of outlet blade angle, cavitation, NPSH, Thoma's cavitation factor, priming of pumps, installation, specific speed, performance characteristics of centrifugal pump, series and parallel operation of pumps, system resistance curve, selection of pumps. Dimensional and Model analysis of hydraulic machines	
Unit-6: Centrifugal & Axial Compressor	**[07 Hrs.]**
Centrifugal compressor: Classification of compressors, Construction, velocity diagram, flow process on T-S Diagram, Euler's work, actual work input, performance characteristics, various losses in centrifugal compressor, Introduction to Gas Turbines. **Axial Compressor:** Construction, stage velocity triangles and its analysis, enthalpy entropy diagram, stage losses and efficiencies, performance characteristics. [No numerical treatment]	
Text Books: 1. Turbines, Compressors & Fans, S.M. Yahya, Tata-McGraw Hill 2. Turbomachines, B. U. Pai, Wiley India 3. Fluid mechanics and hydraulic machines, Dr. R.K. Bansal 4. Hydraulic Machines, Dr. J. Lal, Metropolitan Book Co. Pvt. Ltd., Delhi. 5. Hydraulics, Fluid Mechanics and Machinery, Modi P N & Seth S N, Standard Book House, New Delhi. 6. R. Yadav, Steam and Gas Turbines and Power Plant Engineering, VII edition, Central Publ. House.	
Reference Books: 1. William W. Perg, Fundamentals of Turbomachinery, John Wiley & Sons. 2. Thermal Turbomachines, Dr. Onkar Singh, Wiley India 3. V. P. Vasandani, Theory of Hydraulic Machinary, Khanna Publishers, Delhi. 4. Karassik, Hand Book of Pumps, Tata McGraw Hills Ltd., New Delhi. 5. S.L. Dixon, Fluid Mechanics, Thermodynamics of Turbomachinery, IV edition, Butterworth-	

Heinemann Publ., 1966.

Term-Work

List of Experiments

1. Verification of impulse momentum principle

2. Study and trial on impulse water turbine (Pelton wheel) and plotting of main and operating characteristics

3. Study and trial on any one hydraulic reaction turbine (Francis/Kaplan) and plotting of main and operating characteristics

4. Study and trial on centrifugal pump and plotting operating characteristics

5. Study and trial on centrifugal air compressor and plotting its characteristics

6. Visit to hydro/steam power plant and report to be submitted.

7. Study of different types of nozzles and trial on convergent-divergent air/steam nozzle.

8. Study of axial flow compressors/ centrifugal air blower.

9. Study of multi-staging of steam turbines.

10. Design of pumping system installation using manufacturers' catalogue, specific to housing or industrial application.

11. Visit to pumping station and report to be submitted.

Notes

1. Eight experiments from above list should be performed; out of which at least four trials should be conducted. Data from any one trial performed should be analyzed by using suitable software.

2. Visit to Hydro or Steam power plant is compulsory

Activity (Any One):

1. Visit to hydro/steam power plant to understand construction and working of the type of turbine employed and to observe the power generation process of the respective power plant.

2. PowerPoint presentation by group on any topic related to advanced fluid mechanics or computational fluid dynamics.

3. Simulation of flow process in any turbo machine using any suitable software such as Scilab, OpenFOAM, ANSYS, etc.

ME24313B- HEATING, VENTILATION AND AIR-CONDITIONING		
Teaching Scheme:	**Credits: 04**	**Examination Scheme:**
TH: 03 Hrs./Week **PR : 02 Hrs./Week**	**Theory : 03** **Practical: 01**	**CAA: 10 Marks** **In-Semester Exam: 30 Marks** **End-Semester Exam: 60 Marks** **Oral Exam: 30 Marks**

Prerequisites:

Thermodynamics, Applied Thermodynamics, Fluid Mechanics, Heat and Mass transfer.

Objectives:

1. To understand and compare different refrigerants with respect to properties, applications and Environmental issues and air refrigeration systems.
2. To understand Multi stage compression cycles and multistage evaporator systems.
3. To understand various components, operating and safety controls employed in Refrigeration and air conditioning systems and advanced refrigeration systems.
4. To understand the basic air conditioning processes on psychometric charts, human comfort and to provide the knowledge of indoor and outdoor air quality requirements.
5. To study the ventilation and infiltration in air conditioning and duct design for various comfort conditions and industrial air conditioning systems.
6. To understand advanced A/C systems and heat pump.

Course Outcomes:

On completion of the course the learner will be able to;

CO1. ANALYSE different air-craft refrigeration systems and EXPLAIN the properties, applications and environmental issues of different refrigerants.

CO2. ANALYSE multi pressure refrigeration system used for refrigeration applications.

CO3. DISCUSS types of compressors, condensers, evaporators and expansion valves along with regulatory and safety controls and DESCRIBES Transcritical and ejector refrigeration systems.

CO4. ESTIMATE cooling load for air conditioning systems used with concern of design conditions and indoor quality of air.

CO5. DESIGN air distribution system along with consideration of ventilation and infiltration.

CO6. EXPLAIN the working of types of desiccants, evaporative, thermal storage, radiant cooling, clean room and heat pump systems.

Course Contents

Unit-1: Gas Cycle Refrigeration and Refrigerants	**[08 Hrs.]**
Gas Cycle Refrigeration: Application to air-craft refrigeration, Simple system, Bootstrap, Regenerative, reduced ambient system, Concept of Dry Air Rated Temperature (DART) **Refrigerants:** Introduction, Definition and requirement, Classification of refrigerants, Designation of refrigerants, Desirable properties of Refrigerants-Thermodynamic, Chemical and Physical. Properties of ideal refrigerant. Environmental issues like ODP, GWP & LCCP. Selection of environment friendly refrigerants, Alternative refrigerants, Secondary refrigerants, Anti-freeze solutions, Zeotropes and Azeotropes, Refrigerant recovery, reclaims, recycle and recharge.	
Unit-2: Practical aspects of Vapor Compression and Advanced Refrigeration Systems	**[06 Hrs.]**
Major components of refrigeration cycle: Types of compressors, Characteristics of reciprocating and centrifugal compressors, Types of evaporators, Types of condensers and Types of expansion valves. **Safety Controls:** LP/HP cut-off, Low temperature control, Frost control, Motor overload control, Oil pressure failure control. Capacity control of different compressors **Advanced Refrigeration System:** Transcritical cycle and their types, Simple ejector refrigeration system (analysis and numerical).	
Unit-3: Multi Pressure Systems Systems	**[08 Hrs.]**
Multistage or compound system: Need of multi staging, Two stage compression with flash gas removal, flash intercooler and complete multistage compression system. **Multi evaporator system**: single compressor-individual expansion valve, single compressor-multiple expansion valve, individual compressor-multiple expansion valve, individual compressor with compound compression and flash inter cooling. (Limited to two evaporators). Ammonia-CO2 cascade cycle.	
Unit-4: Applied Psychrometry	**[06 Hrs.]**

Psychrometric Chart, Psychrometric processes using BPF, ADP, SHF, RSHF, GSHF, ESHF, ERSHF and adiabatic mixing of two air streams. Heat load estimation: - Air conditioning, heating & cooling load calculations.

Envelop Load estimation: Concept of sol-air temperature, Time lag & Decrement method and ETD or CLTD methods

Thermal Comfort: Basic parameters, Thermodynamics of human body, Thermal comfort and Comfort charts, Factors affecting thermal comforts.

Indoor Air Quality (IAQ): Indoor air contaminants, Basic strategies to improve indoor air quality Outdoor Design Conditions: Outdoor air requirements for occupants, Use of outdoor weather data in design, Outdoor weather characteristics and their influence.

Unit-5: Ventilation, Infiltration & Air Distribution Systems (Ducts)	**[06 Hrs.]**

Ventilation and infiltration: Natural ventilation, Mechanical ventilation. **Duct Design**: Definition of duct and types of ducts, Economic factors influencing duct layout, Materials for ducts and its specification, Flow through duct, Pressure in ducts, Friction loss in ducts, Friction chart for circular ducts, Equivalent diameter of a circular duct for rectangular sections, Methods of duct designs. (Numerical treatment on duct design). **Air Distribution System**: Factors considered in air distribution system, (simple numerical). Types of air distribution devices. Fan coil unit, Fan laws, Types of fans used air conditioning applications, Types of supply air outlets, Selection and location of outlets, Filters, Diffusers, Grillers, and Dampers.

Unit-6: Advanced Air Conditioning Systems	**[06 Hrs.]**

Advanced AC Systems: Working of summer, winter and all year round AC systems, all air system, all water system, air water system, variable refrigerant flow and variable air volume systems, unitary and central air conditioning.

Desiccant-Based Air Conditioning Systems: Introduction, Sorbents & Desiccants, Dehumidification, Liquid spray tower, Solid packed tower, Rotary desiccant dehumidifiers, Hybrid cycles, Solid desiccant Air-Conditioning (Theoretical treatment) Evaporative Cooling Air Conditioning Systems, Thermal storage Air Conditioning systems, Clean room Air Conditioning systems, Radiant cooling. (No numerical), Heat pumps and its different circuits.

Text Books:

1. Arora C. P., Refrigeration and Air Conditioning, Tata McGraw-Hill.

2. Manohar Prasad, Refrigeration and Air Conditioning, Willey Eastern Ltd, 1983.

3. McQuiston, -Heating, Ventilating, and Air Conditioning: Analysis and Design 6th Edition, Wiley India.

4. Arora and Domkundwar, Refrigeration & Air Conditioning, Dhanpatrai & Company, New Delhi.

5. Khurmi R.S. and Gupta J.K., Refrigeration and Air conditioning, Eurasia Publishing House Pvt.Ltd, New Delhi, 1994.

6. Ballaney P.L., Refrigeration and Air conditioning, Khanna Publishers, New Delhi, 1992.

7. S.N.Sapali, Refrigeration and Air conditioning, Eastern Economy Edition.

8. Arora R.C., Refrigeration and Air Conditioning, PHI, India.

Reference Books:

1. Dossat Ray J, Principles of refrigeration, S.I. version, Willey Eastern Ltd, 2000.

2. Stockers W.F and Jones J.W., Refrigeration and Air conditioning, McGraw Hill International editions 1982.

3. Threlkeld J.L, Thermal Environmental Engineering, Prentice Hall Inc., New Delhi.

4. Aanatnarayan, Basics of refrigeration and Air Conditioning, Tata McGraw Hill Publications.

5. Roger Legg, Air Conditioning System Design, Commissioning and Maintenance.

6. ASHRAE Handbook (HVAC Equipments) & ISHRAE handbook.

7. Shan Wang, Handbook of Refrigeration and Air Conditioning, McGraw Hill Publications.

8. Wilbert Stocker, Industrial Refrigeration, McGraw Hill Publications.

9. ASHRAE, Air Conditioning System Design Manual, IInd edition, ASHRAE.

Web References (NPTEL)

1. https://onlinecourses.nptel.ac.in/noc22_me135/preview
2. https://nptel.ac.in/courses/112105128
3. https://onlinecourses.nptel.ac.in/noc21_me106/preview

Activity (Any One)

1. Use tools like mustimeters, refrigerant gauges, and airflow meters to inspect and test HVAC systems and components. Identify and troubleshoot problems such as refrigerant leaks or electrical failures.

2. Work on installing new HVAC systems, including ductwork and electrical components, in different settings.

3. Design complete duct systems and diffusers, using software like Revit MEP, to create comprehensive HVAC layouts.

4. Learn about the four main types of HVAC systems: split systems, hybrid systems, duct-free systems, and packaged heating and air systems.

5. Study the functions of HVAC systems in green buildings, including heating, ventilation, make-up air, cooling, and exhaust.

List of Practicals

The student shall complete the following activity as a Term Work (Any eight experiments, No. 8 or 9 are compulsory)

1. Test on Ice plant test rig.

2. Performance Simulation of Central Air-conditioning plant using Newton Raphson Method.

3. Test on air-conditioning system for cooling load estimation

4. Performance analysis of Counter flow or cross flow cooling tower. (Theoretical/Practical)

5. Building heat load simulation using suitable software (Trace 700, Energy plus etc.)

6. Design of cold storage with process layout.

7. Analysis of VCC by Cool pack software.

8. Visit to Refrigeration or cold storage Plant

9. Visit to the Air Conditioning Plant.

10. Trial on heat pump/ejector/cascade/desiccant/evaporative systems

ME24314A- INDUSTRIAL ENGINEERING & QUALITY CONTROL		
Teaching Scheme:	**Credits: 04**	**Examination Scheme:**
TH: 03 Hrs./Week **PR : 02 Hrs./Week**	**Theory : 03** **Practical: 01**	**CAA: 10 Marks** **In-Semester Exam: 30 Marks** **End-Semester Exam: 60 Marks** **Oral Exam: 30 Marks**

Prerequisites: Objectives:

Basic concepts of Mathematics and Mechanical Engineering, Industrial Orientation.

Course Objectives:

This course gives an introduction to the world of manufacturing and other work systems, associated terminologies and activities, various basic models and methods to help understand basic factory operations, and in performance assessment and quality control.

1. To introduce the concepts, principles, and framework of Industrial Engineering and various productivity enhancement approaches.
2. To introduce different time study and work measurement techniques for productivity improvement.
3. To introduce various aspects of facility design and functions of Production Planning and Control.
4. To acquaint the students with inventory management concepts
5. To acquaint the students' knowledge Quality Control Techniques/Statistical Tools.

Course Outcomes:

Learner will be able to:

CO1. EVALUATE the productivity and IMPLEMENT various productivity improvement techniques.

CO2. APPLY work study techniques and UNDERSTANDS its importance for better productivity.

CO3. DEMONSTRATE the ability to SELECT plant location, appropriate layout and material handling equipment.

CO4. USE of Production planning and control tools for effective planning, scheduling and managing the shop floor control.

CO5. PLAN inventory requirements and EXERCISE effective control on manufacturing requirements.

CO6. APPLY Quality Control Techniques/ Statistical Tools appropriately.

Course Contents

Unit-1: Introduction to Industrial Engineering and Productivity	**[06 Hrs.]**
Introduction to Industrial Engineering, Historical background and scope, Contribution of Taylor, Gilbreth, Gantt, Maynard, Ford, Deming and Ohno. Introduction- Production systems and their classifications; JIT manufacturing system, Toyota production systems- KANBAN model, and elimination of waste, Lean and green manufacturing and TQM. Productivity: Definition of productivity, Measures of Productivity, Total Productivity Model, Need for Productivity Evaluation, Productivity measurement models, Productivity improvement approaches, Principles, Productivity Improvement techniques – Technology based, Material based, Employee based, Product based techniques. (Numerical on productivity measurement).	
Unit-2: Work Study	**[06 Hrs.]**
Method Study: Introduction and objectives, Areas of application of work study in industry, Selection and Basic procedure. Recording techniques, Operations Process Chart, Flow Process Chart (Man, Machine & Material) Multiple Activity Chart, Two Handed process chart, Flow Diagram, String Diagram and Travel Chart, Cycle and chrono cycle graphs, SIMO chart, Therbligs, Micro motion and macro-motion study: Principles of motion economy. Work Measurement: Techniques, time study, steps, work sampling, Determination of time standards. Observed time, basic time, normal time, rating factors, allowances, standard time, and standard time determination. (Numerical). Introduction to PMTS, MTM, and MOST.	
Unit-3: Production Facility Design	**[06 Hrs.]**
Plant Location: Introduction, Factors affecting location decisions, Multi-facility location. Plant Layout: Principles of Plant layout and Types, factors affecting layout, methods, factors governing flow pattern, travel chart for flow analysis, analytical tools of plant layout, layout of	

manufacturing shop floor, repair shop, services sectors, and process plant. Layout planning, Quantitative methods of Plant layout and relationship diagrams. Dynamic plant layout

Material Handling: Objectives and benefits of Material handling, Relationship between layout and Material handling, Equipment selection

Ergonomics: Introduction to ergonomics and human factors Engineering. Value Engineering: VE concepts, Principles, Methodologies and standards, methods of functional analysis.

Unit-4: Production Planning and Control	**[06 Hrs.]**

Production-Types and methods of Production, and their Characteristics, functions and objectives of Production Planning and Control, Steps: Process planning, Loading, Scheduling, Dispatching and Expediting with illustrative examples, Capacity Planning, Aggregate production planning and Master production scheduling.

Introduction to a line of balance, assembly line balancing, and progress control

Forecasting Techniques: Causal and time series models, Moving average, Exponential smoothing, Trend and Seasonality. (Numerical) .Break Even analysis and simple numerical.

Unit-5: Inventory and Inventory Control	**[06 Hrs.]**

Purchase Management: Purchase management, incoming material control. Acceptance sampling and inspection. Vendor rating system.

Inventory: Functions, Costs, Classifications, Deterministic inventory models and Quantity discount. Selective inventory management ABC, VED, and FSN analysis.

Inventory Control: EOQ (Numerical), concepts, type of Inventory models-deterministic and probabilistic, Selective inventory control, Fundamental of Material Requirement Planning (MRP-I), Manufacturing Resource Planning (MRP-II), Enterprise Resource Planning (ERP) and Supply Chain Management (SCM).

Unit-6: Quality Control	**[06 Hrs.]**

Introduction: Meaning of Quality, Quality of Product, Quality of Service, Cost of Quality, Value of Quality, and Difference between Inspection, Quality Control and Quality Assurance, Role of Quality in Present day environment.

Introduction to Quality Control: Meaning of quality Control, 100% Inspection and Selective Inspection and Statistics in Selective inspection.

Introduction to Statistical Quality Control: Control Charts, X, R, P and C Charts, Sampling inspection, OC Curves and Sampling Plan,

Text Books:

1. O. P. Khanna, Industrial engineering and management, Dhanpat Rai publication

2. M Mahajan, Industrial Engineering and Production Management, Dhanpat Rai and Co.

3. Martend Telsang, Industrial Engineering, S. Chand Publication.

4. Banga and Sharma, Industrial Organization & Engineering Economics, Khanna publication

5. J.M. Juran & F.M.Gryna , Quality Planning and Analysis.

6.. Juran's Quality Control Handbook

7. E.L.Grant & R.S. Kearenworth, Statistical Quality Control.

8. Kaoru Ishikawa, Guide to Quality Control, Asian Productivity Organisation, Tokyo.

Reference Books:

1. Askin, Design and Analysis of Lean Production System, Wiley, India

2. Introduction to Work Study by ILO, ISBN 978-81-204-1718-2, Oxford & IBH Publishing Company, New Delhi, Second Indian Adaptation, 2008.

3. H. B. Maynard, K Jell, Maynard's Industrial Engineering Hand Book, McGraw Hill Education.

4. Zandin K.B., Most Work Measurement Systems, ISBN 0824709535, CRCPress,2002

5. Martin Murry, SAP ERP: Functionality and Technical Configuration, SAP Press.

6. Barnes, Motion and time Study design and Measurement of Work, Wiley India

7. Sumanth, D.J, "Productivity Engineering and Management", TMH, New Delhi, 1990.

8. Edosomwan, J.A, "Organizational Transformation and Process re- Engineering", British Cataloging in publications, 1996.

9. Prem Vrat, Sardana, G.D. and Sahay, B.S, "Productivity Management - A systems approach", Narosa Publications, New Delhi, 1998.

10. Francis, R.L., and White, J.A, "Facilities layout and Location", Prentice Hall of India, 2002.

11. James A. Tompkins, John A. White, "Facilities Planning", Wiley, 2013

12. Richard L. Francis, Leon F Mc Ginnes and John A. White, "Facility Layout and Location An

Analytical Approach", PHI, 1993

13. G. K. Agarawal, "Plant Layout and Material Handling", Jain Brothers, 2007

14. Introduction to Work Study, International Labor Organization, Third Revised Edition.

15. Spearman and Hopp, 2011, Factory Physics, 3rd ed., Waveland Press.

Web References:

1. https://nptel.ac.in/courses/112107249

2. https://onlinecourses.nptel.ac.in/noc25_me64/preview

3.https://onlinecourses.nptel.ac.in/noc25_me181/preview

4.https://onlinecourses.nptel.ac.in/noc20_me43/preview

For completing above any six assignments from 1 to 9 by using any suitable simulation software like WITNESS /Flex slim and other sources.

1. Case study based Assignment on Method Study.

2. Hands on Assignment on application of Work Measurement technique(s).

3. Assignment on simulation of Routing & Scheduling Model

4. Assignment on simulation of Manufacturing System / Service System Operations for demand forecasting of the given product using any two methods.

5. Assignment on simulation determination of EOQ and plot the graphs.

6. Assignment on analysis of Manufacturing / Service Operation for Capacity Planning.

7. Case study based assignment on supply chain model.

8. Assignment on analysis of (selected) plant layout modeling and simulation for bottleneck / line balancing.

9. Assignment on analysis of material handling system - modeling simulation for the selected plant layout.

Use of computational tools [such as Minitab / Matlab / MS Excel] are recommended (Any one) from 10 & 11

10. Analyze the fault in given batch of specimens by using seven quality control tools for engineering application. Submission of these assignments USING STANDAED FORMATS.

11. Determination of process capability from given components and plot variable control

chart/ attribute chart.

13.Industrial visit to manufacturing company (Compulsory)

Activity-(Any one)

1.Simulation study of large systems such as hospitals, super markets, railway network, airport operations, manufacturing systems using all steps in simulation study, starting with problem conceptualization, data collection, input data analysis, model building, model verification and validation, conduct simulation experiments, make observations and recommendations, write a report.

OR

2. Advanced topics: Agent based models, system dynamics models, Introduction to augmented reality based simulation, virtual reality simulations, Interactive simulation, Digital Twins, Gaming models.

OR

3. Any one NPTEL certification Couse

https://nptel.ac.in/courses/112107249

https://onlinecourses.nptel.ac.in/noc25_me64/preview

https://onlinecourses.nptel.ac.in/noc25_me181/preview

https://onlinecourses.nptel.ac.in/noc20_me43/preview

ME24314B- FINITE ELEMENT ANALYSIS		
Teaching Scheme:	**Credits: 04**	**Examination Scheme:**
TH: 03 Hrs./Week **PR : 02 Hrs./Week**	**Theory : 03** **Practical: 01**	**CAA: 10 Marks** **In-Semester Exam: 30 Marks** **End-Semester Exam: 60 Marks** **Oral Exam: 30 Marks**

Prerequisites: Objectives:

Engineering Mathematics, Strength of Materials / Mechanics of Materials, Engineering Mechanics and Numerical Methods or Matrix Methods.

Course Objectives:

- To introduce the basic concepts and procedures used in the Finite Element Method (FEM) for solving engineering problems.
- To develop the ability to formulate and solve one-dimensional and two-dimensional engineering problems using FEM.
- To understand isoparametric formulation, numerical integration techniques and mesh quality criteria used in finite element analysis.
- To apply finite element techniques to practical problems such as heat transfer, structural analysis and other engineering applications.
- To introduce advanced topics such as nonlinear analysis and dynamic analysis in FEM.

Course Outcomes:

The students will be able to learn:

CO1: Understand the fundamental concepts, procedures and mathematical approaches used in Finite Element Analysis.

CO2: Formulate and analyze one-dimensional elements such as bar and truss elements using the finite element method.

CO3: Develop stiffness matrices and solve two-dimensional finite element problems such as plane stress and plane strain conditions.

CO4: Apply isoparametric formulation and numerical integration techniques in finite element modeling.

CO5: Analyze steady-state heat transfer problems using finite element formulation.

CO6: Understand the concepts of nonlinear and dynamic analysis in engineering problems using the finite element method.

Course Contents

Unit-1: Fundamental Concepts of FEA	**[06 Hrs.]**
Introduction – Brief history of FEM, general FEM procedure , advantages and disadvantages of FEM, consistent units system. Introduction to different approaches used in FEA such as direct approach, variational approach, weighted residual method, energy approach, Galerkin method and Rayleigh–Ritz approach. Element Quality Criterion:-Jacobian, Aspect ratio, Warpage, Minimum and Maximum angles, Average element size, Minimum Length, skewness, Tetra Collapse etc., Higher Order Element vs Mesh Refinement, Geometry Associate Mesh, Mesh quality, Mesh independent test.	
Unit-2: 1D Elements	**[06 Hrs.]**
Types of 1D elements. Displacement function, global and local coordinate systems, order of element, primary and secondary variables, shape functions and their properties. Bar and Truss Element - Element stiffness matrix, Assembling stiffness Equation, Load vector, stress and reaction forces calculations. Temperature effect on Bar Element- Calculation due to uniform temperature change, Stress and reaction forces calculations.	
Unit-3: 2D Elements	**[06 Hrs.]**
Types of 2D elements. Formulation of elemental stiffness matrix and load vector for plane stress/strain problems such as Linear Strain Rectangle (LSR) and Constant Strain Triangle (CST). Pascal's triangle, primary and secondary variables, properties of shape functions. Assembly of global stiffness matrix and load vector, boundary conditions, solving for primary variables (displacement), overview of axi-symmetric elements.	
Unit-4: Isoparametric Elements	**[06 Hrs.]**
Concept of isoparametric elements. Terms: isoparametric, superparametric and subparametric elements. Isoparametric formulation of bar element. Coordinate mapping – Natural coordinates, area coordinates (for triangular elements), higher order elements (Lagrangian and serendipity elements), convergence requirement, patch test, uniqueness of mapping – Jacobian matrix. Numerical integration – 2 and 3 point Gauss quadrature, full and reduced	

integration, submodeling and substructuring.

Unit-5: 1D Steady State Heat Transfer Problems	**[06 Hrs.]**

Introduction, governing differential equation, steady-state heat transfer formulation of 1D element for conduction and convection problems, boundary conditions and solving for temperature distribution.

Unit-6: Non Linear and Dynamic Analysis	**[06 Hrs.]**

Non-Linear Analysis: Introduction to Nonlinear Problems, Comparison of Linear and Nonlinear analysis, Types of Nonlinearities, Stress-strain measures for Nonlinear analysis, Analysis of Geometric, Material Nonlinearity, Solution Techniques for Nonlinear analysis, Newton Raphson Method, Essential steps in Nonlinear analysis. Dynamic Analysis: Introduction to Dynamic Analysis, Comparison of Static and Dynamic analysis, Time domain and frequency domain, Types of loading, Simple Harmonic motion, Free vibration, Boundary conditions of free vibration, Solution.

Text Books:

1. Chandrupatla T. R. and Belegunda A. D., Introduction to Finite Elements in Engineering, Prentice Hall India, 2002.

2. J. N. Reddy, An Introduction to the Finite Element Method, McGraw Hill Series in Mechanical Engineering, 2005.

3. S. S. Bhavikatti, Finite Element Analysis, New Age International Publishers, Third Edition, 2015.

4. P. Seshu, Text Book of Finite Element Analysis, PHI Learning Private Limited, New Delhi, 10th Printing, 2012.

5. Gokhale N. S., Deshpande S. S., Bedekar S. V., and Thite A. N., Practical Finite Element Analysis, Finite to Infinite, Pune, First Edition, 2008.

6. G. Lakshmi Narasaiah, Finite Element Analysis, BS Publications / BSP Books, Second Edition, 2020.

Reference Books:

1. David V. Hutton, Fundamentals of Finite Element Analysis, Tata McGraw-Hill, 2017.

2. Daryl L. Logan, A First Course in the Finite Element Method, Fourth Edition, Thomson

Canada Limited, 2007.

3. K. J. Bathe, Finite Element Procedures, Prentice-Hall of India (P) Ltd., New Delhi, 1996.

4. Cook R. D., Finite Element Modeling for Stress Analysis, John Wiley & Sons Inc., 1995.

5. G. R. Liu and S. S. Quek, The Finite Element Method – A Practical Course, ButterworthHeinemann, 2013.

6. Fagan M. J., Finite Element Analysis: Theory and Practice, Pearson / Prentice Hall, 2012.

7. S. Moaveni, Finite Element Analysis: Theory and Application with ANSYS, Pearson, Third Edition, 2011.

8. Mukhopadhyay M. and Sheikh A. H., Matrix and Finite Element Analyses of Structures, Ane Books Pvt. Ltd., 2009.

9. O. C. Zienkiewicz, The Finite Element Method: Its Basis and Fundamentals, Sixth Edition, Elsevier Butterworth-Heinemann, 2005.

Web References:

7. Basics of Finite Element Analysis – Prof. Nachiketa Tiwari, IIT Kanpur
8. Advanced Finite Element Analysis – Dr. R. Krishnakumar, IIT Madras
9. Finite Element Analysis for Welding Analysis – Prof. Swarup Bag, IIT Guwahati
10. ANSYS Tutorials – University of Alberta

Guidelines for Activity (Any 1)

1. **Presentation on Applications of Finite Element Analysis (FEA)**
   Students prepare a **short presentation (8–10 minutes)** on real engineering applications of FEA such as:
   - Automotive component analysis
   - Aircraft structure analysis
   - Biomedical implants
   - Thermal analysis in electronics
   - Stress analysis of machine components

   Students should explain **problem description, modeling approach, and interpretation of results.**
2. **Analytical vs FEM Solution Comparison**
   Students solve a **simple structural problem** (such as a bar element or cantilever beam):

- First using **analytical method**
- Then using **finite element analysis**

Students compare **displacement, stress, and error percentage.**

Guidelines for Lab /TW Assessment (Any 8)

1. Structural Linear Analysis of a 1D Bar Element using finite element formulation to determine nodal displacements, stresses and reaction forces.
2. Truss Structure Analysis using 1D Elements to evaluate member forces, nodal displacements and stress distribution.
3. Beam Element Analysis for structural problems such as simply supported and cantilever beams.
4. Modal Analysis of Mechanical Systems such as spring–mass systems, simply supported beam and cantilever beam to determine natural frequencies and mode shapes.
5. Plate / Shell Element Analysis for structural problems including linear structural analysis.
6. Thermal Analysis of Engineering Components including steady-state and transient heat transfer analysis.
7. Coupled Field Analysis (Structural–Thermal Interaction) to study the effect of temperature variation on structural deformation and stress.
8. Finite Element Analysis of Machine Components using 3D Solid Elements for stress and deformation evaluation.
9. Nonlinear Analysis of Assembly using Contact Elements and Nonlinear Buckling Analysis of Beam Elements.

ME24314C- RENEWABLE ENERGY TECHNOLOGY		
Teaching Scheme:	**Credits:04**	**Examination Scheme:**
TH: 03 Hrs./Week **PR : 02 Hrs./Week**	**Theory : 03** **Practical: 01**	**CAA: - 10 Marks**
		In-Semester Exam: 30 Marks
		End-Semester Exam: 60 Marks
		OR Exam: 30 Marks

Prerequisites: Basic knowledge of Physics, Thermodynamics, and Basic Electrical Engineering.

Objectives:

1. To understand the basic concepts and significance of renewable energy resources.
2. To explain the principles and working of solar energy systems and their applications
3. To analyze the performance and potential of wind energy conversion systems.
4. To examine ocean, geothermal, and other alternative energy technologies.
5. To apply renewable energy concepts for estimating energy generation and basic system design.

Course Outcomes:

The students will be able to learn:

CO1: Explain the basic concepts and significance of renewable energy resources.

CO2: Analyze solar radiation characteristics and applications of solar energy systems.

CO3: Evaluate the performance and design aspects of solar thermal systems.

CO4: Analyze the working principles and performance of wind energy conversion systems.

CO5: Explain the principles of ocean, geothermal, and other alternative energy sources.

CO6: Apply renewable energy concepts to estimate energy generation and system requirements for practical applications.

Course Contents

Unit-1:Solar Energy Basics and Applications	**[06 Hrs.]**
Introduction to Solar Energy; Solar Constant; Solar Radiation at the Earth's Surface; Solar Radiation Geometry; Solar Radiation Measurements; Solar Radiation Data; Estimation of Average Solar Radiation; Solar Radiation on Tilted Surfaces; Solar Water Heating; Space Heating of Buildings; Space Cooling of Buildings; Solar Electric Power Generation (Photovoltaics); Agricultural and Industrial Process Heat; Solar Distillation; Solar Pumping; Solar Furnace; Solar Cooking; Solar Greenhouses.	
Unit-2: Solar Thermal Systems	**[06 Hrs.]**
Introduction to Solar Thermal Systems: Physical Principles of Conversion of Solar Radiation into Heat; Solar Energy Collectors; Flat Plate Collectors; Concentrating Collectors (Focusing Type); Advantages and Disadvantages of Concentrating Collectors over Flat Plate Collectors; Cylindrical Parabolic Concentrating Collector; Selective Absorber Coatings; **Introduction to Solar Photovoltaic (PV) Systems:** Working Principle of Photovoltaic Effect; Types of Solar Cells; PV Module and Array; Basic PV System Components; Applications of Solar PV Systems. Solar Energy Storage Systems; Solar Pond; Principle of Operation of Non-convective Solar Pond; Extraction of Thermal Energy; Applications of Solar Ponds.	
Unit-3: Wind Energy	**[06 Hrs.]**
Introduction; Basic Principles of Wind Energy Conversion; Nature of the Wind; Power in the Wind; Forces on the Blades; Wind Energy Conversion; Wind Data and Energy Estimation; Site Selection Considerations; Basic Components of a WECS (Wind Energy Conversion System); Classification of WEC Systems; Advantages and Disadvantages of WECS; Types of Wind Machines (Wind Energy Collectors); Horizontal-Axis Machines; Vertical-Axis Machines; Analysis of Aerodynamic Forces Acting on the Blade; Generating Systems; Schemes for Electric Generation; Generator Control; Load Control; Energy Storage; Applications of Wind Energy; Interconnected System; Safety; Environmental Aspects.	
Unit-4: Green Hydrogen and Fuel Cells	**[06 Hrs.]**

Introduction to Hydrogen Energy; Concept of Green Hydrogen; Importance of Hydrogen in Clean Energy Transition; Hydrogen Production Methods; Electrolysis of Water; Thermochemical Methods of Hydrogen Production; Hydrogen Production using Renewable Energy Sources; Hydrogen Storage Methods; Hydrogen Transportation and Safety; Introduction to Fuel Cells; Design and Principle of Operation of Fuel Cells (H_2–O_2 Fuel Cell); Classification and Types of Fuel Cells; Conversion Efficiency of Fuel Cells; Electrodes and Electrolytes used in Fuel Cells; Work Output and EMF of Fuel Cells; Advantages and Limitations of Fuel Cells; Applications of Fuel Cells in Power Generation, Transportation, and Portable Systems.

Unit-5: Energy from Biomass	**[06 Hrs.]**

Bio-mass: Biomass types, Characteristics (Ultimate analysis, Proximate analysis, Calorific value, Physical Properties, Thermodynamic properties, Feedstock Handling Characteristic, Thermogravimetric analysis), Biomass estimation, Biomass formulation. Bio-fuel: Introduction to bio-fuels, feedstocks for bio-fuel production, bio-diesel, bio-hydrogen, concept of bio-refinery Thermo-chemical conversion: Pyrolysis, Liquefaction and Gasification, Gasifier and types. Gas production, environmental effects, Producer gas utilization, Biomass integrated gasification/combined cycles systems. Bio-chemical Conversion: Biodegradation, Aerobic Digestion, Anaerobic digestion; Biogas digester types and biogas utilization

Unit-6: Alternative Renewable Energy Sources	**[06 Hrs.]**

Energy from Oceans; Tidal Energy; Wave Energy; Ocean Thermal Energy Conversion (OTEC); Principles of Ocean Energy Conversion; Components and Working of Ocean Energy Systems; Geothermal Energy; Geothermal Resources and Classification; Geothermal Power Plants; Applications of Geothermal Energy; Magneto Hydrodynamic (MHD) Power Generation; Principles of MHD Generation; MHD Power Plant Components; Advantages and Limitations of MHD Power Generation; Hybrid Renewable Energy Systems; Environmental Impact and Future Prospects of Renewable Energy Sources.

Text Books:

1. G. D. Rai, “Non-Conventional Sources of Energy”, 5th ed. Khanna Publishers, New Delhi, India, 2017, ISBN-10: 81-7409-073-8.
2. C. S. Solanki, “Renewable Energy Technologies: A Practical Guide for Beginners”, PHI

Learning Pvt. Ltd., New Delhi, India, 2015, ISBN-13: 978-8120344765.

3. B. H. Khan, "Non-Conventional Energy Sources", 2nd ed. New Delhi, India: Tata McGraw-Hill Education, 2012, ISBN-13: 978-007107820.
4. D. P. Kothari, K. C. Singal, and R. Ranjan, "Renewable Energy Sources and Emerging Technologies". PHI Learning Pvt. Ltd., New Delhi, India, 2011, ISBN-13: 978-8120344710.

Reference Books:

1. S. P. Sukhatme and J. K. Nayak, "Solar Energy: Principles of Thermal Collection and Storage", 4th ed., Tata McGraw-Hill Education, New Delhi, India, 2017, ISBN-13: 978-1259003190.
2. J. Twidell and T. Weir, "Renewable Energy Resources", 3rd ed. London, Taylor & Francis,, UK: Routledge, 2015, ISBN-13: 978-1138785025.
3. G. Boyle, "Renewable Energy: Power for a Sustainable Future", 3rd ed. Oxford University Press, Oxford, UK, 2012, ISBN-13: 978-0199545333.

Web References (NPTEL)

1. Renewable Energy Engineering: Solar, Wind And Biomass Energy Systems ,by Prof. R. Anandalakshmi, Prof. Vaibhav Vasant Goud- IIT Guwahati.

(https://onlinecourses.nptel.ac.in/noc26_ch26/preview)

2. Non-conventional energy Resources, By Prof. Prathap Haridoss -IIT Madras **(https://onlinecourses.nptel.ac.in/noc26_ge38/preview)**

Guidelines for Activity

Any one activity should be performed

1. NPTEL course certification recommended by faculty
2. To design the solar PV system to meet a specific electrical load using solar radiation data for any domestic or commercial application. (Reference: https://www.pvsyst.com/en/)
3. To evaluate the wind energy potential of a selected location using wind speed data and design micro wind mills for household applications. (Reference: https://qblade.org/downloads/)

Guidelines for Lab /TW Assessment (Any Eight)

1. Experiment on solar photovoltaic (PV) panel to measure voltage, current, and power under different load conditions.
2. Study of IoT-based solar energy monitoring systems using sensors and microcontrollers (Arduino/ESP32).
3. Prediction of solar power generation using basic AI/ML algorithms.
4. CFD Analysis of Solar Air Heater for Heat Transfer and Airflow Characteristics
5. Determination of wind power using wind speed data and estimation of wind energy potential.
6. Case study and report on renewable energy applications in India (solar, wind, ocean, geothermal).
7. Performance Analysis of Hydrogen Fuel Cell
8. Modeling and Simulation of Solar Photovoltaic (PV) System using MATLAB/Simulink
9. Modeling and Simulation of Wind Energy Conversion System (WECS) using MATLAB/Simulink
10. Industrial visit to any renewable energy power plant.

Multidisciplinary Minor Course-3 ET24053: - Internet of Things (IoT)		
Teaching Scheme: Theory: 02 Hours/Week Practical: 02 Hours/Week	Credits 03	Examination Scheme: Activity: 10 Marks End Sem: 60 Marks Term work: 30 Marks

Prerequisite Courses, if any:

1. Digital Systems
2. Microcontrollers

Course Objectives:

- To introduce the fundamentals concepts of an IoT.
- To give Insights IoT Design Outlooks with sensors and actuators.
- To make aware of the usage of communication protocols in IoT.
- To develop design skills with IoT Physical devices and endpoints with programming.

Course Outcomes: On completion of the course, learner will be able to

- CO1: Comprehend and analyze concepts of IoT.
- CO2: Interpret IoT Design Outlooks with sensors and actuators.
- CO3: Comprehend the operation of communication protocols in IoT.
- CO4: Describe various IoT Physical devices and endpoints with programming and apply programming skills for application development.

Course Contents

Unit I: IoT Fundamentals (06 Hrs.)

Internet of Things -History, Basic Definitions, Characteristics, Features, & Design; Physical & Logical Design of IoT; Enabling Technologies in IoT; About Things in IoT; The Identifiers in IoT; IoT frameworks, IoT and M2M; Networking- Types, Devices, and Topology.

Unit II: IoT Design Outlooks and Sensors & Actuators (06 Hrs.)

M2M and IoT; Devices and Gateways in IoT; Introduction to the sensors and actuators with types and principle of working; Basics of Wireless Sensor Networks; Fundamentals of Edge and Cloud; Cloud Services: SaaS, IaaS, PaaS & XaaS.

Unit III: Communication Protocols (06 Hrs.)

Short-Range Communication Protocols: Zigbee, Z-Wave, Bluetooth, Wi-Fi

Long-Range Communication Protocols: LoRaWAN

Application Layer Protocols: MQTT (Message Queuing Telemetry Transport) CoAP (Constrained Application Protocol), HTTP/HTTPS

Unit IV: IoT Physical devices and endpoints (06 Hrs.)

IoT development and deployment hardware; Interfacing sensors and actuators to the development

boards; Applications of IoT: Home Automation, Smart Cities, Energy, Agriculture, Health and Lifestyle, etc. What is the IoE? Difference between IoT and IoE. Introduction to IIoT.

Textbooks:

1.Hakima Chaouchi, – The Internet of Things Connecting Objects to the Web ISBN: 978-1- 84821-140-7, Wiley Publications

2. Olivier Hersent, David Boswarthick, and Omar Elloumi, –The Internet of Things: Key Applications and Protocols, Wiley Publications

3. Vijay Madisetti and ArshdeepBahga, –Internet of Things (A Hands-On-Approach), 1st Edition, VPT, 2014.

References:

1. Daniel Minoli, –Building the Internet of Things with IPv6 and MIPv6: The Evolving World of M2M Communications‖, ISBN: 978-1-118-47347-4, Willy Publications

2. Pethuru Raj and Anupama C. Raman, "The Internet of Things: Enabling Technologies, Platforms, and Use Cases", CRC Press

3.http://www.cse.wustl.edu/~jain/cse570-15/ftp/iot_prot/index.html

4. https://onlinecourses.nptel.ac.in/noc17_cs22/course

List of Experiments

Group A: Any 4

1. Study & Survey of various IoT platforms.
2. Study & Survey of various development boards for IoT. Understanding the process of OS installation on Raspberry Pi.
3. Program digital read/write using LED and Switch.
4. Measure the distance of an object using ultrasonic sensor.
5. Interfacing sensors (Temperature, PIR, LDR) and actuators (Motors) using Arduino.

Group B: Any 3

6. Install Google App Engine. Create a Hello world app and other simple web applications using python / java. Use GAE launcher to launch the web applications.
7. Building a Motion-Activated Alarm System using Arduino/Raspberry Pi.
8. To study simple application using IoT analytics platform service.
9. IoT based small project implementation on the topics based on small problem statements of the fields like Smart Home (Home Automation), social issues and environmental issues etc. This project can be built on any IoT simulation platform like TinkerCAD.

HOD E&TC
Dr BH Patil

Dean Autonomy
Dr CB Nayak

Dean Academics
Dr SM Bhosle

Principal
Dr SB Lande

Head
Department of Electronics & Telecommunication Engineering
VPKBIET, Baramati-413133

VPKBIET BARAMATI
Affiliated to S.P.P.U. Pune Id No./PU/PN/Engg./152/2000
PUNE (MS.)

Principal
Vidya Pratishthan's
Kamalnayan Bajaj Institute of Engineering & Technology, Baramati
Vidyanagari, Baramati-413133

OE24003 - DESIGN THINKING		
Teaching Scheme:	**Credits:03**	**Examination Scheme:**
TH: 03 Hrs./Week	**Theory : 03**	**CAA: - 10 Marks**
		In-Semester Exam: 30 Marks
		End-Semester Exam: 60 Marks

Prerequisites: No strict academic prerequisites. However the general prerequisites are

- Basic understanding of problem-solving techniques
- Interest in creativity and innovation
- Ability to observe and analyze real-world situations
- Basic communication and teamwork skills
- Open mindset towards learning and experimentation

Objectives:

1. To UNDERSTAND **the principles and process of design thinking**

2. To UNDERSTAND **empathy and user-centric problem-solving skills**

3. To DEFINE **Problem statement clearly**

4. To enhance CREATIVITY **and ideation techniques**

5. To IMPART **students to prototype and test engineering solutions**

6. To APPLY **design thinking in real-world engineering problems**

Course Outcomes:

On completion of the course, learner will be able to

CO1. Explain the concepts and importance of design thinking

CO2. Analyze user needs using empathy tools

CO3. Formulate clear problem statements

CO4. Generate innovative design solutions

CO5. Develop prototypes and test solutions

CO6. Apply design thinking in multidisciplinary engineering contexts

Course Contents

Unit-1: Introduction to Design Thinking	**[06 Hrs.]**
Definition, importance, and scope of design thinking, Evolution of design thinking in engineering and industry Principles: Human-centered design, empathy, experimentation, Comparison with traditional engineering problem-solving approaches, Case studies from engineering domains	
Unit-2: Empathy and User Understanding	**[06 Hrs.]**
Concept of empathy in design, User research methods: interviews, observation, surveys, Creating user personas and empathy maps, Stakeholder analysis, Identifying user needs and pain points	
Unit-3: Problem Definition and Ideation	**[06 Hrs.]**
Framing problem statements (How Might We questions), Root cause analysis techniques, Brainstorming methods (SCAMPER, mind mapping, brainwriting), Divergent and convergent thinking, Idea evaluation and selection	
Unit-4: Prototyping and Modeling	**[06 Hrs.]**
Importance of prototyping in engineering design, Types of prototypes: low-fidelity and high-fidelity, Tools and techniques (sketching, CAD models, mockups), Rapid prototyping methods Iterative design process	
Unit-5: Testing and Implementation	**[08 Hrs.]**
User testing methods and feedback collection, Usability testing and validation, Iteration based on feedback, Feasibility, viability, and desirability analysis, Preparing solutions for real-world implementation	

Unit-6: Design Thinking in Engineering Practice	**[08 Hrs.]**

Application in various engineering fields (mechanical, civil, software, etc.), Sustainability and ethical considerations, Innovation and entrepreneurship, Team collaboration and multidisciplinary design, Capstone project: solving a real-world problem using design thinking

Text Books:

1. S. Salivahanan, S. Suresh Kumar, D. Praveen Sam, "Introduction to Design Thinking", Tata McGraw Hill, First Edition, 2019.

2. Kathryn McElroy, "Prototyping for Designers: Developing the Best Digital and Physical Products", O'Reilly, 2017.

3. Michael G. Luchs, Scott Swan, Abbie Griffin, "Design Thinking – New Product Essentials from PDMA", Wiley, 2015.

4. Vijay Kumar, "101 Design Methods: A Structured Approach for Driving Innovation in Your Organization", 2012.

Reference Books:

1. Change by Design, Tim Brown, Revised Edition, Harper Business, 2019.
2. The Design of Everyday Things, Don Norman, Revised and Expanded Edition, Basic Books, 2013.
3. Creative Confidence, Tom Kelley and David Kelley, 1st Edition, Crown Business, 2013.
4. The Art of Innovation, Tom Kelley, 1st Edition, Currency/Doubleday, 2001.
5. The Design of Business, Roger Martin, 1st Edition, Harvard Business Press, 2009.

Online Resource:

1. https://www.mygreatlearning.com/academy/learn-for-free/courses/introduction-to-design-thinking
2. https://www.simplilearn.com/learn-design-thinking-basics-free-course-skillup
3. https://alison.com/course/basics-of-design-thinking
4. https://www.open.edu/openlearn/science-maths-technology/design-innovation/design-thinking/
5. https://freedesignthinking.com/
6. https://alison.com/course/design-thinking-generating-ideas-stories-and-prototypes-revised
7. https://www.ideou.com/
8. https://dschool.stanford.edu/resources

Web References (NPTEL)

- https://onlinecourses.nptel.ac.in/noc25_mg106/preview
- https://www.nptel.ac.in/courses/110106124
- https://archive.nptel.ac.in/noc/courses/noc20/SEM2/noc20-mg38/
- https://onlinecourses-archive.nptel.ac.in/noc19_mg23/preview
- https://elearn.nptel.ac.in/shop/nptel/design-thinking-a-primer/
- https://elearn.nptel.ac.in/shop/iit-workshops/completed/introduction-to-design-thinking-its-creative-tools/

Guidelines for Activity (Any One)

1. Case Studies – Analyze real-world applications of Design Thinking
2. Presentation on Innovations in Design Thinking – Present new advancements
3. Empathy mapping exercise
4. Persona creation
5. Problem statement drafting
6. Ideation workshop (SCAMPER / Brainstorming)
7. Prototype development (paper/model/digital)
8. Final mini-project (team-based)