T. Y. B. Tech : Mechanical Engineering
[Level 5.5, UG] Semester -V

Sr. No.	Course Type	Course Code	Course Name	L	T	P	S	Cr	Evaluation Scheme (Weightage in %)				
									Theory			Laboratory	
									MSE	TA	ESE	ISE	ESE
01	PCC		Heat Transfer	3	0	2	1	4	30	20	50	50	50
02	PCC		Dynamics of Machine	3	0	2	0	4	30	20	50	50	50
03	PCC		Metrology & Measurement	2	0	2	1	3	30	20	50	50	50
04	PEC		Program Elective Course -I (Specify List) *	3	0	0	1	3	30	20	50	-	-
05	MDM		Multidisciplinary Minor II	3	1	0	0	4	30	20	50	-	-
06	RM		Open Elective Course III	2	0	0	2	2	30	20	50	-	-
07	ELC		Internship 1#	0	0	0	0	1	-	-	-	CIE-100	
08	ELC		Project-I	0	0	4	0	2	-	-	-	CIE-100	
							Total Credit	**23**					

Summer Internship (Industry /R&D / Academic Institute) after IV semester during summer vacation and evaluation will be done at the start of V semester. Duration minimum One and a maximum Two months.

*Program Elective Course I – Discipline-wise List			
Design Engineering	**Thermal Engineering/Fluid Science**	**Manufacturing Science and Engineering**	**Interdisciplinary**
Finite Element Methods (FEM)	Fluid Dynamics	Advanced Manufacturing Technology	Fundamentals of Green Hydrogen Technology
Experimental Stress Analysis	Modern IC Engines	Operations Research	Machine Learning
	Steam and Gas Turbine		Renewable Energy Resources

V-1 : Heat Transfer

Course Code	CourseName	Teaching Scheme (Weightage in Hr.)					EvaluationScheme (Weightage in %)				
		L	T	P	S	Cr	Theory			Laboratory	
							MSE	TA	ESE	ISE	ESE
<tbd>	Heat Transfer	3	0	2	1	4	30	20	50	50	50

Course Outcomes:

Students who successfully complete this course will have demonstrated an ability to:

CO 1: Analyze the various modes of heat transfer and implement the basic heat conduction equations for steady one dimensional thermal system

CO 2: Quantify heat transfer through extended surfaces and unsteady state conduction.

CO 3: Obtain analytical solution for two dimensional steady state heat conduction.

CO 4: Estimate forced and free convection heat transfer coefficient by using appropriate correlations.

CO 5: Develop a solution for radiation heat exchange between two or more surfaces**.**

CO 6: Analyze heat exchanger performance by using the method of LMTD and method of heat exchanger effectiveness.

Syllabus:

Unit	Contents	Hrs
1	**One dimensional steady state heat conduction:** Introduction, derivation of Generalized heat conduction equation in Cartesian coordinates, Fourier, Laplace and Poission's equation. Generalized heat conduction equation in cylindrical and spherical co-ordinates. (no derivation). Heat conduction through a composite slab, cylinder and sphere, effect of variable thermal conductivity, critical radius of insulation, thermal contact resistance. Conduction with heat generation for plane wall, cylinder and sphere.	**8**
2	**Extended surfaces and unsteady state heat conduction:** Types and applications of fins, heat transfer through extended surfaces, derivation of temperature distribution equations and heat transfer through fins of constant cross-sectional area. Effectiveness and efficiency of a fin, overall efficiency of fin array. Errors in the measurement of temperature in a thermowell. System with negligible internal thermal resistance, Biot and Fourier numbers. Lumped heat capacity method, use of Heisler charts.	**8**

3	**Two dimensional steady state heat conduction:** Introduction to analytical method two dimensional steady state heat conduction in rectangular plates , two dimensional steady state heat conduction in semi-infinite plates. Numerical solutions of steady 2D conduction, conduction shape factors for common geometries.	**6**
4	**Convective Heat Transfer:** Local and average convective coefficient, hydrodynamic and thermal boundary layer. Laminar and turbulent flow over a flat plate and through a duct, friction factor, drag and drag co-efficient. Dimensional analysis in free and forced convection, physical significance of the dimensionless numbers related to free and forced convection. Empirical correlations for free and forced convection for heat transfer in laminar and turbulent flow over a flat plate and through a duct. Introduction to condensation and boiling, pool boiling, critical heat flux, burnout point, forced boiling. Film and drop wise condensation (No numerical treatment)	**7**
5	**Radiation:** Fundamental concepts, black body radiation, Planck's distribution law, Wien's displacement law and the Stefan-Boltzmann law. Transmissivity, absorptivity,reflectivity, the grey, black and real surface. Radiation shape factor, use of shape factor charts, Kirchhoff's law, Lambert's cosine law. Heat exchange between non-black bodies, heat exchange between two infinitely parallel planes and cylinders, Radiation shields, heat exchange by radiation, between two finite black/gray surfaces. Gas radiation (elementary treatment only). Solar radiation, irradiation, radiation potential, electrical network method of solving radiation problems.	**7**
6	**Heat exchangers:** Heat exchangers classification, overall heat transfer coefficient, heat exchanger analysis, use of log mean temperature difference (LMTD) for parallel and counter flow heat exchangers, LMTD correction factor, fouling factor. The effectiveness-NTU method for parallel and counter flow heat exchangers. Design considerations of heat exchanger.	**6**

Laboratory Course Work:

Students have to perform any eight of the following experiments, make a report, and submit it as Term work for evaluation

List of Experiments:

1. Determination of thermal conductivity of a metal rod
2. Determination of thermal conductivity of insulating powder.
3. Determination of thermal conductivity of a given liquid.
4. Determination of thermal resistance of composite slab
5. Determination of Time required to Heat/Cool a body (Unsteady State Heat Conduction)
6. Determination of heat transfer coefficient in natural convection
7. Determination of heat transfer coefficient in forced convection for flow through cylinder
8. Determination of critical heat flux
9. Determination of emissivity of given surface
10. Determination of Stefan Boltzmann constant
11. Determination of effectiveness of heat exchanger (shell and tube type, cross flow type and plate type)

Suggested learning resources:
Text Books

1. S.C.Arora, V. M. Domkundwar, A.V.Domkundwar, A course in Heat and Mass Transfer, Dhanpat Rai and Co. Pvt. Ltd, New Delhi
2. S. P Sukhatme, A Text Book of Heat Transfer, University Press, 4th Edition, 2005
3. R.K.Rajput, Heat and Mass Transfer, S. Chand and Co. Pvt. Ltd, New Delhi.

Reference Books

1. Incropera and Dewitt: Fundamentals of Heat and Mass Transfer, John Wiley and Sons, NY.
2. P.K.Nag, Heat and Mass Transfer, Tata McGraw-Hill, 2011
3. Yunus A. Cengel, Heat Transfer: A Practical Approach, McGraw-Hill Higher Education, 2002
4. J.P. Holman: Heat Transfer; McGraw-Hill, 1996
5. C.P. Kothandaraman, S. Subramanyam, Heat and Mass Transfer Data Book, New Age International Publishers, Mumbai.

Weblinks:
https://archive.nptel.ac.in/courses/112/108/112108149/

V-2 : Dynamics of Machine

Course Code	Course Name	Teaching Scheme (Weightage in Hr.)					Evaluation Scheme (Weightage in %)				
							Theory			Laboratory	
		L	T	P	S	Cr	MSE	TA	ESE	ISE	ESE
<tbd>	Dynamics of Machine	3	0	2	0	4	30	20	50	50	50

Course outcomes:

Upon completion of the course, students will be able to:

CO.1: Choose appropriate gear drives (spur, helical, bevel, worm) and analyze speed and torque in gear trains for specific applications.

CO.2: Apply design principles to select appropriate belt for specific applications based on power transmission requirements, speed ratios, and other factors.

CO.3: Apply principles of friction, design, and operation of various clutch and brake systems. Understand and apply balancing techniques for static and dynamic balancing of various machines and components, including reciprocating and rotating masses.

CO.4: Understand the principles of gyroscopes and their applications in various engineering fields.

CO.5: Analyze single and multi-degree-of-freedom systems subjected to free, damped, and forced vibrations. This includes understanding natural frequencies, damping, and response to various excitations.

Syllabus:

Unit	Contents	Hrs.
1	**Gears II:** Helical gear, spiral gear, bevel gear and worm gear. Gear trains	7
2	**Belt Drives:** Introduction, Velocity ratio, Belt length, limiting ratio, power transmitted, centrifugal tensions, condition for maximum power transmission.	5
	Clutches and Brakes: Clutches and Brakes: types, power and torque transmission, and absorption derivations.	8
3	**Balancing:** Static and dynamic balance, balancing of revolving several masses on several planes, balancing of reciprocating masses in single and multi cylinder engines, balancing machines.	8
4	**Gyroscope:** Introduction, Gyroscopic couple, Gyroscopic effects, Gyroscopic ship stabilization.	6

5	**Mechanical vibrations:** Fundamentals, undamped and damped free vibrations of single degree freedom system, forced vibration of single degree of freedom system, critical speed of shafts.	**8**

Laboratory Course work:

List of Experiments:

1. Determination of torque for epicyclic gear train.
2. Determinations of torque and power transmitted by various friction drives.
3. Determination of unbalanced forces in rotating masses.
4. Determination of unbalanced forces in reciprocation engines.
5. Determination of Gyroscopic couple.
6. Determination of natural frequency of transverse vibrations of a bar.
7. Determination of damping coefficient of torsional vibrations.
8. Determination of node point of two rotor system.
9. Determination of critical speed of shaft of single rotor.

Suggested learning resources:

Textbooks:

- John Hannah and Stephens, R. C., "Mechanics of Machines: Advanced Theory and Examples", 1970,
  Hodder; Student international edition ISBN 0713132329 Edward Arnold London
- Ballaney, P., "Theory if Machines and Mechanisms", 2005, ISBN 9788174091222 Khanna Publications
- Bansal, R. K., "Theory of machines", Laxmi Publications Pvt. Ltd, New Delhi

Reference Books:

- Bevan Thomas, "The Theory of Machines", 3rd edition, CBS publishing
- Uicker Jr, J. J., Penock G. R. and Shigley, J. E., "Theory oif Machines and Mechanisms' 2003, Tata McGraw Hill
- Ramamurthy, V., "Mechanisms of Machines", 3rd edition, ISBN 978-1842654569, Narosa Publishing House

Weblinks:

https://archive.nptel.ac.in/courses/112/105/112105125/
https://archive.nptel.ac.in/courses/112/106/112106137/

V-3 : Metrology and Measurements

Course Code	Course Name	Teaching Scheme (Weightage in Hr.)					Evaluation Scheme (Weightage in %)				
		L	T	P	S	Cr	Theory			Laboratory	
							MSE	TA	ESE	ISE	ESE
<tbd>	Metrology and Measurements	2	0	2	1	3	30	20	50	50	50

Course Outcomes:
Students will be able to :

CO 1: Determine geometry and dimensions of components in engineering applications using various measuring instruments.

CO 2: Design gauges to meet desired needs within realistic constraints

CO 3: Select the sensor/transducer for practical applications.

CO 4: Understand methods of measurement for various quantities like force, torque, strain, flow, displacement, velocity/speed and acceleration.

Syllabus:

Unit	Contents	Hrs.
1	**Linear and Angular Measurements**, **Interferometry, Measurement System:** **Introduction:** Meaning of Metrology, Precision, Accuracy, Methods and Errors in Measurement, Calibration. **Linear Measurement:** Standards, Line Standards, End Standard, Wavelength Standard, Classification of Standards, Precision and Non -Precision Measuring instruments and their characteristics, Slip Gauges. **Interferometry:** Introduction, Flatness testing by interferometry, NPL Flatness Interferometer. Study of Measuring Machines, Recent Trends in Engineering Metrology, use of interferometers for length, angle and surface roughness measurement **Angle Measurement:** Sine bars, Sine Centers, Uses of sine bars, angle gauges, Autocollimator Angle Dekkor, Constant deviation prism. **Measurement System Analysis:** Introduction, Influence of temperature, operator skills and the instrument errors etc.	6
2	**Design of gauges, Interferometers and Comparators, Measuring Machines:** **Limits, Fits and Tolerances:** Meaning of Limit, Fits and Tolerance, Cost – Tolerance relationship, concept of Interchangeability, Indian Standard System. **Design of limits Gauges:** Types, Uses, Taylor‘s Principle, Design of Limit Gauges. **Inspection of Geometric parameters**: Straightness, Flatness, Parallelism, Concentricity, Squareness, and Circularity. **Comparators:** Uses, Types, Advantages and Disadvantages of various types of Comparators.	7

	Measuring Machines: Theory of Coordinate Metrology, Universal Measuring Machines, Coordinate Measuring Machines (CMM), different configurations of CMM, Principle, Error involved, calibration, Probing system, automated inspection system.	
3	**Surface Finish Measurement, Screw Thread Metrology, Gear Metrology:** **Surface Finish Measurement:** Surface Texture, Meaning of RMS and CLA values, Roughness Measuring Instruments, Tactile and Non-tactile measuring instruments, difference between waviness and roughness, Grades of Roughness, Specifications, Assessment of surface roughness as per IS, Relationship between surface roughness and Manufacturing Processes. **Screw Thread Metrology:** External Screw Thread Terminology, Floating Carriage Instruments, Pitch and flank Measurement of External Screw Thread, Application of Tool Maker‘s Microscope, Use of Profile Projector. **Gear Metrology:** Spur Gear Parameters, Gear Tooth Thickness Measurement: Gear Tooth Vernier Caliper, Constant Chord Method.	8
4	**Introduction to Mechanical Measurements:** Importance of Measurements, Classification of measuring instruments, generalized measurement system, types of inputs for measurements. Concepts such as Linearity, Sensitivity, Static error, Precision, Reproducibility, Threshold, Resolution, Hysteresis, Drift, Span & Range etc. Errors in Measurements, Classification of errors in measurements, First order instruments and its response to step, ramp, sinusoidal and impulse inputs.	5
5	**Measurement Methods and Devices:** **Displacement Measurement:** Transducers for displacement measurement, potentiometer, LVDT, Capacitance Types, Digital Transducers (optical encoder), Nozzle Flapper Transducer. **Velocity Measurement:**Tachometers, Tacho generators, Digital tachometers and Stroboscope. **Acceleration Measurement:** theory of accelerometer and vibrometers, strain gauge based and piezoelectric accelerometers. **Strain Measurement:** Theory of Strain Gauges, gauge factor, temperature Compensation, Bridge circuit, orientation of strain gauges for force and torque, Strain gauge based load cells and torque sensors.	5
6	**Measurement – Methods and Devices:** **Pressure Measurement**: Elastic pressure transducers viz. Bourdon tubes, diaphragm, bellows and piezoelectric pressure sensors, High Pressure Measurements, Bridge man gauge, Vacuum gauges viz. McLeod gauge, Ionization and Thermal Conductivity gauges. **Temperature Measurement:** Thermocouple, Resistance thermometers, Thermistors, Pyrometers. Liquid in glass Thermometers, Bimetallic strip. **Flow measurement:** Venturimeter, Orifice meter, Rotameter.	5

Laboratory Course Work:

List of Experiments:

The term work shall consist of the conduction of any eight experiments from the list given below.

1. Determination of Linear dimensions of a part using Precision and non-precision measuring Instruments.
2. Precision angular measurement using a setup of Sine Bar and Slip Gauges

3. Measurement of straightness, circularity, run out ,and total run out.
4. Measurement of screw thread parameters using Floating Carriage Micrometer.
5. Surface Finish measurement using a suitable instrument.
6. Interferometry: Measurement of surface flatness using an optical flat.
7. Study and Measurement of Parameters Using Profile Projector.
8. Exercise on Design of Limit Gauges using Taylor's Principles.
9. Demonstration of Digital Comparator and Pneumatic Comparator
10. Demonstration of CMM and Vision Measurement Machine
11. Measurement of temperature using RTD
12. Measurement of flow using a flowmeter

Assignments:

1. Exercise on Design of Limit Gauges using Taylor's Principles.
2. Develop a Matlab-Simulink model for First order instruments for various inputs.

Suggested learning resources:

Text Books:

- R. K. Jain, A Text book of Engineering Metrology, Khanna Pblications Pvt. Ltd.18th Edition, 2002
- I.C. Gupta, A Text book of Engineering Metrology, Dhanpat Rai Pblications Pvt. Ltd.6th Edition, 2004
- Anand Bewoor, Vinay Kulkarni, Metrology and Measurement, Tata McGraw-Hill, first edition 2009.
- N. V. Raghavendra, L. Krishnamurthy, Engineering Metrology and Measurements, Oxford University Press,1st edition 2013
- R. K. Rajput, A textbook of measurement and metrology ,S.K. Kataria & Sons, 2013.
- R. K. Jain ,Mechanical and Industrial Measurements, Khanna Publishers,1995
- A. K. Sawhney, Mechanical Measurement and Control, Dhanpat Rai & Co. (P) Limited, 2017

Reference Books

- G.M.S. De Silva, Basic Metrology for ISO 9000 Certification Elsevier Publications, 3rd Edition 2002.
- Ernest Doebelin and Dhanesh Manik,Measurement Systems , McGraw-Hill, 6th Edition, 2017.

PEC-4.1 : Finite Element Method

Course Code	Course Name	Teaching Scheme (Weightage in Hr.)					Evaluation Scheme (Weightage in %)				
							Theory			Laboratory	
		L	T	P	S	Cr	MSE	TA	ESE	ISE	ESE
ME-xxxx	Finite Element Analysis	**3**	**0**	**0**	**1**	**3**	30	20	50	--	

Course outcomes:
Students who successfully complete this course will have demonstrated an ability to:

CO 1: Understand and formulate engineering problems using physical, mathematical, and numerical modeling concepts.

CO 2: Apply variational methods and weighted residual approaches (Galerkin, Petrov-Galerkin) to derive finite element equations in 1D & 2D.

CO 3: Formulate and simulate FEM models for trusses and beams, and analyze results for real-world applications.

CO 4: Model and analyze single-variable 2D field problems using FEM with various elements and numerical integration techniques for real-world engineering applications.

CO 5: Identify, analyze, and minimize sources of errors in finite element solutions.

CO 6: Solve eigenvalue problems involving vibration analysis of spring-mass systems and beams using FEM techniques.

Syllabus:

Unit	Contents	Hrs.
1	**Introduction:** ● Overview of engineering problems and solution methods, illustrated through an example: physical system - physical model - mathematical model (Governing differential equation) - solution methods - final solution. Emphasizes the need for numerical methods and types of engineering analysis. ● Concepts of shape functions, approximation functions, local and global coordinates. ● Initial Value Problems, Boundary value problems and solution methods, Direct approach – example, advantage and limitations. ● Introduction to steps of FEM for the generic problems.	**4**
2	**Variational Methods in FEM:** ● Elements of calculus of variation, Strong form and weak form, equivalence between strong and weak forms, Rayleigh-Ritz method, Principle of Minimum Potential Energy . Euler -Lagrange Equations from a Functional . ● Method of weighted residuals – Galerkin and Petrov-Galerkin approach;Least Squares . Examples - Axially loaded bar, Heat Conduction/Convection Pin-Fin for 1-D Problems, governing equations,	**6**

	discretization, derivation of element equation, assembly, imposition of boundary condition and solution, examples.	
3	**Trusses & Beams:** ● Finite element formulation for plane trusses. ● Finite element formulation for Euler-Bernoulli beams (Governing differential equation, Characteristics of formulation for problems - FEM procedure - Computation of derived quantities like strains and stresses from the nodal values of the field variables, Result post-processing).	**5**
4	**2-D Problem from structural mechanics:** ● Introduction to 2-dimensional problem from structural mechanics static analysis, different elements (triangular, rectangular, quadrilateral, axis symmetric, etc.), shape functions. ● Basic concepts of Plain stress and Plain strain. Constant strain triangular element Stiffness Matrix and Equation. Finite element Solution of a plane stress Problem. ● Higher order elements, isoparametric elements. Need for numerical integration and co-ordinate transformation, Gauss- Legendre integration technique for numerical integration, linear elasticity problems & heat conduction. ● Application of FEM to Axisymmetric problems, Axisymmetric solids under rotation.	**7**
5	**Eigen-value problems:** Eigen value problems, Mass and stiffness matrices, 2 Dof and 3 Dof spring mass problems. Tranverse vibration of beams. Methods to find Eigen values and Eigen vectors.	**3**
6	**Thermal Stresses and Errors in FEM:** ● Thermal Stresses – Formulation – Numericals (1D & 2D). ● Sources of errors, error analysis, remedies to minimize the errors.	**3**

Suggested learning resources:

Textbooks:

1. Daryl L Logan "A First Course in Finite Element Method" Sixth Edition.
2. Introduction to Finite Element Method By J.N .Reddy.
3. Cook R.D. "Concepts and applications of finite element analysis" Wiley, New York, 1981.
4. Bathe K.J., Cliffs, N.J. "Finite element procedures in Engineering Analysis", Englewood. Prentice Hall, 1981.

Reference Books:

1. Jacob Fish and Ted Belytschko. 2007. A First Course in Finite Elements. John Wiley & Sons, Inc., Hoboken, NJ, USA.
2. Desai C.S. and J.F. Abel "Introduction to the finite element method." New York, Van Nostrand Reinhold, 1972.
3. O. P. Gupta, "Finite and boundary element methods in Engineering", Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, 2000.
4. Chandrupatla and Belegundu "Introduction to finite elements in Engineering", Prentice Hall of India Pvt. Ltd. New Delhi, 2001.

PEC-4.2 : Fluid Dynamics

Course Code	Course Name	Teaching Scheme (Weightage in Hr.)					Evaluation Scheme (Weightage in %)				
		L	T	P	S	Cr	Theory			Laboratory	
							MSE	TA	ESE	ISE	ESE
ME-xxxx	Fluid Dynamics	**3**	**0**	**0**	**1**	**3**	30	20	50	--	

Course outcomes:

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

CO1: Understand and define the fluid flow problems along with range of governing parameters

CO2: Use the governing equations for different flow conditions for exact and approximate solutions.

CO3: Differentiate the different fluid flow patterns, flow regimes and its effects.

CO4: Devise the fluid flow problems of the industrial base.

CO5: Design and develop experimental procedures for internal and external fluid flow conditions.

Syllabus:

Unit	Contents	Hrs.
1	**Governing equations in Fluid Dynamics:** Reynolds Transport Theorem, Derivation of Continuity and Momentum equations using integral and differential approach, dimensionless form of governing equations, special forms of governing equations.	8
2	**Exact solutions of Navier-Stokes equations:** Fully developed flows, parallel flow in straight channel – Couette flow with and without applied pressure gradients, Fully Developed Flow in a Round Pipe— Poiseuille Flow, unconfined Flow over the horizontal and inclined plate, Creeping flow approximation	7
3	**Potential flow:** Irrotational flow approximations for continuity and momentum equations, Kelvin's theorem, Bernoulli Equation in Inviscid Regions of Flow, Two-Dimensional Irrotational Regions of Flow, Elementary Planar Irrotational Flows – uniform, source, sink, Irrotational Flows Formed by Superposition – doublet, flow past a half body, a Rankine Oval Body, a circular cylinder, lift and drag Forces on Submerged Bodies – stationary and rotating cylinder. Drag Force acting on a rotating cylinder	6
4	**Boundary layer approximation:** Boundary layer equations, Laminar flat plate boundary layer exact solution, Turbulent flat plate boundary layer approximate solution, approximate solution methodology for boundary layer equations, Von-Karman integral	7

	Momentum equation for boundary layer, Pressure gradients in boundary layer flow, Separation of Boundary Layer, Control of Boundary Layer Separation	
5	**Turbulent flow:** Characteristics of turbulent flow, laminar turbulent transition, time mean motion and fluctuations, Reynolds stresses, Prandtl's mixing length theory, derivation of governing equations for turbulent flow- Continuity, Reynolds Navier-Stokes equation, shear stress models, universal velocity distribution law and friction factor in duct flows for very large Reynolds number, Fully developed turbulent flow in a pipe for moderate Reynolds number.	8
6	**Experimental techniques:** Introduction to measurements related to fluid flow, Analysis of experimental data- types of errors, sources of error, uncertainty analysis, Measurement of temperature- thermoelectric thermometry, resistance thermometry, pyrometry, bimetallic and liquid crystal thermometer, Measurement of pressure-U-tube manometer, pressure transducers, Measurement of volume flow rate- orifice plate meter, flow nozzle, venturi meter, rotameter, velocity measurement based on thermal effect - Hot wire Anemometry, Laser Doppler Velocimetry, Particle Image Velocimetry.	6

Suggested learning resources:

Text Books:

1. Introduction to Fluid Mechanics and Fluid Machines, 3rd Edition, Gautam Biswas (Author), S. Chakraborty, McGraw Hill Education.

0. Muralidhar and Biswas, Advanced Engineering Fluid Mechanics, Alpha Science International, 2005

0. Hydraulics and Fluid Mechanics including Hydraulic Machines, Dr. P. N. Modi and Dr. S. M. Seth, Standard Book House, New Delhi

Reference books:

1 Y.A.Cengel, J.M.Cimbala, Fluid Mechanics – Fundamentals and Applications, McGraw Hill, 2004.

2 Irwin Shames, Mechanics of Fluids, McGraw Hill, 2003

3 Fox R.W., McDonald A.T, Introduction to Fluid Mechanics, John Wiley and Sons In 1985

4 Pijush K. Kundu, Ira M Kohen and David R. Dawaling, Fluid Mechanics, Fifth Edition, 2005.

NPTEL Course:
https://nptel.ac.in/courses/101103004

PEC-4.3 : Advanced Manufacturing Technology

Course Code	Course Name	Teaching Scheme (Weightage in Hr.)					Evaluation Scheme (Weightage in %)				
		L	T	P	S	Cr	Theory			Laboratory	
							MSE	TA	ESE	ISE	ESE
ME-xxxx	Advanced Manufacturing Technology	**3**	**0**	**0**	**1**	**3**	30	20	50	--	

Course outcomes:
Students who successfully complete this course will have demonstrated an ability to:

CO 1: Understand the fundamental principles of surface treatment.

CO 2: Learn the principles and techniques used for non-traditional machining.

CO 3: Understand the advanced technologies like ceramic processing.

Syllabus:

Unit	Contents	Hrs.
1	**Surface treatment:** Scope, Cleaners, Methods of cleaning, Surface coating types, and ceramic and organic methods of coating, economics of coating. Electro forming, Chemical vapour deposition, thermal spraying, Ion implantation, diffusion coating, Diamond coating and cladding.	6
2	**Non-Traditional Machining**: Introduction, need, AJM, Parametric Analysis, Process capabilities, USM –Mechanics of cutting, models, Parametric Analysis, WJM –principle, equipment, process characteristics, performance, EDM – principles, equipment, generators, analysis of R-C circuits, MRR, Surface finish, WEDM.	6
3	**Laser Beam Machining:** Principle of working, equipment, Material removal rate, Process parameters, performance characterization, Applications. Plasma Arc Machining – Principle of working, equipment, Material removal rate, Process parameters, performance characterization, Applications. Electron Beam Machining - Principle of working, equipment, Material removal rate, Process parameters, performance characterization, Applications. Electro Chemical Machining – Principle of working, equipment, Material removal rate, Process parameters, performance characterization, Applications.	6
4	**Processing of ceramics:** Applications, characteristics, classification. Processing of particulate ceramics, Powder preparations, consolidation, Drying, sintering, Hot compaction, Area of application, finishing of ceramics. Processing of Composites: Composite Layers, Particulate and fiber reinforced composites, Elastomers, Reinforced plastics, MMC, CMC, Polymer matrix composites.	6
5	**Fabrication of Microelectronic devices:** Crystal growth and wafer preparation, Film Deposition oxidation, lithography, bonding and packaging, reliability and yield, Printed Circuit	6

	boards, computer aided design in microelectronics, surface mount technology, Integrated circuit economics. E-Manufacturing, nanotechnology, micromachining and High-speed Machining, basic principles, working, applications, advantages.	

Suggested learning resources:

Textbooks:

1. Manufacturing Engineering and Technology by Kalpakijian, Addison Wesley, 1995.
2. Foundation of MEMS by Chang Liu, Pearson, 2012.
3. Advanced Machining Processes by V. K. Jain, Allied Publications.

NPTEL Course:
https://onlinecourses.nptel.ac.in/noc24_me154/preview

PEC-4.4 : Fundamentals of Green Hydrogen Technology

<table>
<tr><td rowspan="3">Course Code</td><td rowspan="3">Course Name</td><td colspan="5">Teaching Scheme (Weightage in Hr.)</td><td colspan="5">Evaluation Scheme (Weightage in %)</td></tr>
<tr><td rowspan="2">L</td><td rowspan="2">T</td><td rowspan="2">P</td><td rowspan="2">S</td><td rowspan="2">Cr</td><td colspan="3">Theory</td><td colspan="2">Laboratory</td></tr>
<tr><td>MSE</td><td>TA</td><td>ESE</td><td>ISE</td><td>ESE</td></tr>
<tr><td>ME-xx xx</td><td>Fundamentals of Green Hydrogen Technology</td><td>3</td><td>0</td><td>0</td><td>1</td><td>3</td><td>30</td><td>20</td><td>50</td><td colspan="2">--</td></tr>
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Course Outcomes:
By the end of this course, students will be able to:

CO 1: Explain the concept of the hydrogen economy and classify various hydrogen production pathways, with a focus on green hydrogen.

CO 2: Analyze and compare different hydrogen production technologies, particularly electrolysis methods, and evaluate their efficiency and suitability for renewable energy integration.

CO 3: Design and evaluate hydrogen storage and transportation systems considering technical, safety, and economic aspects.

CO 4: Assess hydrogen utilization technologies including fuel cells and internal combustion systems, and explore their integration in industrial and transportation sectors.

CO 5: Investigate emerging trends, policies, and case studies related to the global and national green hydrogen ecosystem, and propose solutions to current challenges.

Syllabus:

Unit	Contents	Hrs.
1	**Introduction to Hydrogen Economy and Green Hydrogen:** Overview of hydrogen as an energy carrier,Hydrogen economy: concepts, evolution, and need,Classification of hydrogen: grey, blue, green, turquoise,Role of green hydrogen in decarbonization,Current global and Indian scenario: policies, initiatives, and projects,Challenges and opportunities in green hydrogen deployment.	**4**
2	**Hydrogen Production Technologies:** **Electrolysis Techniques:** Alkaline Electrolyzers, Proton Exchange Membrane (PEM) Electrolyzers,Solid Oxide Electrolyser (SOE),Solar and wind energy integration for green hydrogen,Water purification and resource management for electrolysis,Biomass gasification and thermochemical routes,Techno-economic analysis and efficiency comparisons	**6**
3	**Hydrogen Storage and Transportation:** **Physical storage:** Compressed gas, Liquid hydrogen, **Material-based storage**: Metal hydrides, Chemical carriers (ammonia, LOHCs),Storage system design considerations,Transportation methods: Pipelines, Cryogenic tankers, Hydrogen blending in NG pipelines, Safety standards, codes, and regulations	**5**

4	**Hydrogen Utilization and Applications:** **Fuel cells**: PEMFC, SOFC, applications and integration, Hydrogen in internal combustion engines (H2-ICE),Industrial applications: Steel, Fertilizer, Refineries **Mobility and transportation:** Fuel cell electric vehicles (FCEVs), hybrid systems, **Power-to-X technologies:** Synthetic fuels, Ammonia, Methanol	7
5	**Emerging Trends, Challenges, and Future Prospects:** Techno-economic analysis of hydrogen value chain,Hydrogen hubs, microgrids, and sector coupling, Carbon footprint and life-cycle assessment (LCA), Policy framework, incentives, and public-private partnerships, Case studies: National Hydrogen Mission (India), EU Hydrogen Strategy, HyDeploy, etc., Research opportunities and startup ecosystem	6

Textbooks (Recommended for Primary Learning)

1. **"Hydrogen and Fuel Cells: Emerging Technologies and Applications"**
   Author: Bent Sørensen
   Publisher: Academic Press
   Description: Covers hydrogen production, storage, fuel cells, and applications with technical depth. Suitable for engineering students.

2. **"Hydrogen Economy: Supply Chain, Life Cycle Analysis and Energy Transition for Sustainability"**
   Authors: Antonio Scipioni, Alessandra Manzardo, Javier G. Pérez
   Publisher: Academic Press
   Description: Excellent introduction to hydrogen's role in the energy transition, with chapters on production, storage, LCA, and policy.

Reference Books (For Deeper Understanding & Advanced Study)

1. **"Fuel Cell Fundamentals"**
   Authors: Ryan O'Hayre, Suk-Won Cha, Whitney Colella, Fritz B. Prinz Publisher: Wiley
   Description: Comprehensive reference for understanding fuel cell technologies, design, and applications.

2. **"Hydrogen Energy and Vehicle Systems"**
   Author: Scott E. Grasman Publisher: CRC Press
   Description: Focuses on hydrogen applications in transportation, vehicle design, and energy systems integration.

3. **"Green Hydrogen: Renewable Energy for a Low Carbon Future"**
   Editors: V. Subramanian et al. Publisher: CRC Press (Recent publication)
   Description: Covers green hydrogen production, storage, utilization, and policy frameworks—updated with current trends and global case studies.

Supplementary Reading (Reports, White Papers & Journals)

- **IEA Global Hydrogen Review** (International Energy Agency)
- **IRENA Report on Green Hydrogen: A Guide to Policy Making**
- **NITI Aayog – India's Green Hydrogen Policy and Roadmap**
- **Journal:** International Journal of Hydrogen Energy (Elsevier)
- **Journal:** Renewable and Sustainable Energy Reviews (Elsevier)

PEC-4.5 : Experimental Stress Analysis

Course Code	Course Name	Teaching Scheme (Weightage in Hr.)					Evaluation Scheme (Weightage in %)				
							Theory			Laboratory	
		L	T	P	S	Cr	MSE	TA	ESE	ISE	ESE
ME-xxxx	Experimental Stress Analysis	**3**	**0**	**0**	**1**	**3**	30	20	50	--	

Course outcomes:

Students who successfully complete this course will have demonstrated an ability to:

CO 1: Understand the fundamental concepts of stress, strain, and their relationship.

CO 2: Learn the principles and techniques for experimental stress and strain measurement.

CO 3: To analyze experimental data to validate theoretical models.

CO 4: To Gain hands-on experience with modern experimental tools and techniques.

Syllabus:

Unit	Contents	Hrs.
1	**Introduction to Experimental Stress Analysis:** Importance and Scope of Experimental Stress Analysis, Equilibrium equations in 3D, Shear force and bending moment diagrams, Concepts of Stress and Strain tensors. Mohr circle, transformation of stress and strain components in 3D, Principal Stresses and Strains.	6
2	**Constitutive relations, theories of yielding and composite materials:** Constitutive equations in 3D, isotropic materials, anisotropic material, fibre composite materials, theories of yielding, piezo-electric sensors. Overview of Experimental Methods.	4
3	**Measurement of strain through strain gages:** Electrical Resistance Strain Gauges: Working Principles, Types, and Applications. Wheatstone Bridge Circuits and Gauge Factor. Rosette strain gages: Measurement of strain in a thin elastic beam, compare it with theoretical prediction, and study geometrical nonlinearity; measure strain in a circular tube loaded with a torsional member using full bridge.	8
4	**Photoelasticity:** Principles of Photoelasticity: Stress-Optic Law, Plane and Circular Polariscope Techniques, Fringe Patterns: Isoclinics and Isochromatics, Determination of material fringe value, Pure bending moment through four-points bend specimen, study of Saint Venant's principle through photoelasticity	8
5	**Advanced Techniques in Stress Analysis:** Moire' interferometry, Principle, Types, and Applications; Digital Image Correlation (DIC): Principles, Equipment, and Applications; Thermoelastic	6

	Stress Analysis Using Infrared Thermography, Ultrasonic Stress Analysis Methods, Fiber Optic Strain Sensors.	
6	**Applications and Case Studies:** Fiber Optic Strain Sensors, its principle, applications, and its strength and limitations; case studies of applications of various measuring techniques in actual cases in industrial applications.	6

Suggested learning resources:

Textbooks:
- Dally, J. W., and Riley, W. F., Experimental Stress Analysis
- Sadhu Singh, Experimental Stress Analysis
- Srinath, L. S., Experimental Stress Analysis

Reference Books:
- Hetenyi, M., Handbook of Experimental Stress Analysis
- Ramesh, K., Digital Photoelasticity: Advanced Techniques and Applications

Useful Links:
- https://onlinecourses.nptel.ac.in/noc21_me02/preview

PEC-4.5 : Modern IC Engine

Course Code	Course Name	Teaching Scheme (Weightage in Hr.)					Evaluation Scheme (Weightage in %)				
		L	T	P	S	Cr	Theory			Laboratory	
							MSE	TA	ESE	ISE	ESE
<*tbd*>	Modern IC Engine	**3**	**0**	**0**	**1**	**3**	30	20	50	--	

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

CO 1 Construction and operation of IC engine,

CO 2 Fuels and combustion of fuels in SI and CI engine,

CO 3 Conduct performance test and carry out calculations,

CO 4 Formation of exhaust emissions and their controlling measures.

Syllabus:

Unit	Contents	Hrs.
1	**Overview of thermodynamics of fuel-air cycles and real cycles** Otto cycle, Diesel cycle, Atkinson cycle, Stirling cycle, Brayton cycle. Assumptions in fuel air cycle and its analysis, Composition of cylinder gases **Engine construction and operation** Construction and working principle of SI, CI engines and gas turbines, Major engine components, Four stroke and two stroke engines	6
2	**Engine fuels** Basic requirements of engine fuels: Chemical structure of petroleum, Heat value of fuels, Rating of SI Engine fuels, Rating of CI engine fuels, Combustion equation for hydrocarbon fuels, Properties and ratings of petrol and diesel fuels, Fuel supply systems of SI and CI engines, non-conventional fuels for IC engines; LPG, CNG, Methanol, Ethanol, Non-edible vegetable oils, Hydrogen.	5
3	**Carburetor & Fuel Injection systems** Construction and working of carburettor, Inlet and exhaust valve timings, Fuel feed and fuel injection pumps, Petrol injection, Electronic Fuel Injection systems (EFI), Multi-point fuel injection system (MPFI)	5
4	**Combustion in SI and CI Engines:** Ignition systems, Stages of combustion in engines, Flame propagation and factors affecting it, Knocking and pre-ignition, Factors affecting knocking and Control of knocking, Combustion chamber requirements, Turbo charging and super charging, Engine emissions, Engine emissions and emission standards	5

5	**Engine lubrication systems** Engine lubrication systems, Hydrodynamic theory of lubrication, Properties of lubricants, Types of lubricants and additives Grading of lubricating oils, **Engine cooling** Air and water cooling systems, Working principles of air and water cooling systems, Variation of gas temperatures, Components of water cooling system	6
6	**Engine performance and testing of engines** Performance parameters, Engine power, BHP, Fuel consumption, Air consumption, Engine heat balance sheet, Mechanical efficiency, Engine efficiencies, Testing of engines and related numerical problems	6

Suggested learning resources:

Practicals:

1. Engine dismantling and engine assembly: SI and CI engines.
2. Identification of engine components and checking them for defects.
3. Performance testing of SI/CI engine
4. Tailpipe emission testing of given engine

References:

1. Heywood, J. B, , *Internal Combustion Engine Fundamentals*, McGraw Hill Publishing Co., New York, 1990.
2. Sharma, S. P, Chandramohan, *Fuels and Combustion,* Tata McGraw Hill Publishing Co, 1987.
3. Mathur and Sharma, *A course on Internal combustion Engines*, Dhanpat Rai & Sons, 1998.
4. Pulkrabek, W. W., Engineering Fundamentals of the Internal Combustion Engine, Prentice-Hall of India Private Limited, 2002.
5. Prof. P.L. Ballaney, *Internal Combustion Engines,* Khanna Publications, Delhi, India
6. R.K. Mohanty, *A Text Book of Internal Combustion Engines,* Standard Book House, Delhi, India

PEC-4.7 : Operations Research

Course Code	Course Name	Teaching Scheme (Weightage in Hr.)					Evaluation Scheme (Weightage in %)				
							Theory			Laboratory	
		L	T	P	S	Cr	MSE	TA	ESE	ISE	ESE
ME-xxxx	Operations Research	**3**	**0**	**0**	**1**	**3**	30	20	50	--	

Course outcomes:

At the end of the course student will able to:

CO 1: Illustrate the need to optimally utilize the resources in various types of industries.

CO 2: Apply and analyze mathematical optimization techniques to various applications.

CO 3: Demonstrate cost effective strategies in various applications in industry.

CO 4: Demonstrate the use of quantitative techniques in project management.

Syllabus:

Unit	Content	Hrs.
1	**Introduction to operations research and linear programming problem:** Scope, phases, and applications of operations research, advantages and limitations of operations research. Linear Programming Problem (LPP)- formulation and graphical solution to LPP, simplex method, artificial variable technique- Big M method and two-phase method, duality and sensitivity analysis.	8
2	**Transportation, assignment and sequencing problem:** Mathematical formulation of transportation problem (TP), methods to obtain initial basic feasible solution, TP with and without degeneracy. Assignment problem (AP)- Mathematical formulation, variations of AP, Travelling Salesman Problem. Sequencing Problem-Assumptions in sequencing problem, processing of n jobs through two machines, processing of n jobs through three machines.	8
3	**Replacement model and waiting line theory:** Replacement of items whose maintenance and repair cost increases with time ignoring money value and considering money value, replacement of items that fails suddenly- group replacement. Waiting line theory- Kendall's notation, waiting line with single channel Poisson arrivals with exponential service times, infinite population.	8
4	**Games theory and simulation:** Minimax criteria for optimality, characteristics of game, dominance principles, 2X2 game- arithmetic and algebraic method, 2Xn and mX2 game- graphical and method of subgames, 3X3 game- method of matrices Simulation- Monte Carlo simulation, advantages and limitations of simulation, applications of simulation	8
5	**Network analysis:** Network construction, identification of critical path, float calculations, Programme Evaluation and Review Technique (PERT) time calculations, crashing of network, resource scheduling, network updating	8

Suggested learning resources:

Text Books:

- Operations Research- theory, methods & applications, Eighteenth revised edition 2017, S. D. Sharma, Kedar Nath Ram Nath
- Operations Research, Revised and enlarged edition 2012 Prem Kumar Gupta and D S Hira, S Chand & Company Ltd.

Reference Books:

- Operations Research-An Introduction, Ninth edition 2014, Hamdy A Taha, Pearson Education India
- Operations Research: Methods and Problems, Maurice Saseini, Arhur Yaspan and Lawrence Friedman, John Wiley and Sons., New York

PEC-4-8 : Machine Learning

<table>
<tr><th rowspan="3">Course Code</th><th rowspan="3">Course Name</th><th colspan="5">Teaching Scheme (Weightage in Hr.)</th><th colspan="5">Evaluation Scheme (Weightage in %)</th></tr>
<tr><th rowspan="2">L</th><th rowspan="2">T</th><th rowspan="2">P</th><th rowspan="2">S</th><th rowspan="2">Cr</th><th colspan="3">Theory</th><th colspan="2">Laboratory</th></tr>
<tr><th>MSE</th><th>TA</th><th>ESE</th><th>ISE</th><th>ESE</th></tr>
<tr><td>ME-xxxx</td><td>Machine Learning</td><td>3</td><td>0</td><td>0</td><td>1</td><td>3</td><td>30</td><td>20</td><td>50</td><td colspan="2">--</td></tr>
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Course Outcomes:

Students who successfully complete this course will have demonstrated an ability to:

CO 1: Understand Fundamental Concepts of Machine learning.

CO 2: Apply Data Preprocessing Techniques

CO 3: Implement Supervised Learning Algorithms

CO 4: Utilize Unsupervised Learning Methods

CO 5: Develop Deep Learning Models

CO 6: Explore Advanced ML Applications

Syllabus:

Units	Contents	Hrs.
1	**Introduction to AI & Machine Learning in Mechanical Engineering:** History and evolution of AI and ML, Differences between AI, ML, and Data Science. Importance of ML in engineering, Overview of ML approaches: Supervised, Unsupervised, Reinforcement Learning Basic concepts: Reasoning, problem-solving, knowledge representation, planning, perception	6
2	**Feature Engineering and Data Preprocessing:** Importance of data quality and preprocessing, Techniques for feature extraction: Statistical features, Principal Component Analysis (PCA), Feature selection methods, Dimensionality reduction techniques	7
3	**Supervised Learning Algorithms:** Linear and logistic regression, Decision trees and random forests, Support Vector Machines (SVM), K-Nearest Neighbors (KNN), Model evaluation metrics: Accuracy, precision, recall, F1-score	6
4	**Unsupervised Learning and Clustering:** Clustering algorithms: K-Means, Hierarchical clustering, Dimensionality reduction: PCA, t-SNE, Anomaly detection techniques, Applications in mechanical systems: Fault detection, pattern recognition	7

5	**Deep Learning and Neural Networks:** Introduction to neural networks and deep learning, Convolutional Neural Networks (CNNs) for image data, Recurrent Neural Networks (RNNs) for time-series data, Applications in mechanical engineering: Predictive maintenance, image-based inspections	**8**
6	**Advanced Topics and Applications in Mechanical Engineering:** Reinforcement learning and its applications, Physics-informed machine learning models, Integration of ML with Computer-Aided Engineering (CAE) tools, Case studies: Digital twins, smart manufacturing, structural health monitoring	**7**

Suggested learning resources:

Textbooks:

1. Aurélien Géron, Hands-On Machine Learning with Scikit-Learn and TensorFlow Concepts, Tools, and Techniques to Build Intelligent Systems, O'Reilly Media, Inc., 1005 Gravenstein Highway North, Sebastopol, CA 95472.
2. Introduction to Machine Learning with Python by Andreas C. Müller & Sarah Guido
3. Machine Learning For Dummies by John Paul Mueller & Luca Massaron

Reference Books:

1. Tom Mitchell "Machine Learning" McGraw Hill Publication, ISBN :0070428077 9780070428072
2. Marc Peter Deisenroth (Author), A. Aldo Faisal (Author), Cheng Soon Ong (Author), MATHEMATICS FOR MACHINE LEARNING, Cambridge University Press (23 April 2020); Cambridge University Press.

PEC-4.9 : Renewable Energy Resources

<table>
<tr><th rowspan="3">Course Code</th><th rowspan="3">Course Name</th><th colspan="5">Teaching Scheme (Weightage in Hr.)</th><th colspan="5">Evaluation Scheme (Weightage in %)</th></tr>
<tr><th rowspan="2">L</th><th rowspan="2">T</th><th rowspan="2">P</th><th rowspan="2">S</th><th rowspan="2">Cr</th><th colspan="3">Theory</th><th colspan="2">Laboratory</th></tr>
<tr><th>MSE</th><th>TA</th><th>ESE</th><th>ISE</th><th>ESE</th></tr>
<tr><td>ME-xxxx</td><td>Renewable Energy Resources</td><td>3</td><td>0</td><td>0</td><td>1</td><td>3</td><td>30</td><td>20</td><td>50</td><td colspan="2">--</td></tr>
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Course Outcomes (COs):

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

CO 1: Understand the effect of fossil fuels on global warming and their relative impact on the environment.

CO 2: Comprehends the energy scenario of India and the scope of non-conventional energy sources.

CO 3: Describe the difference between non-conventional energy and renewable.

CO 4: Evaluate the performance of the various non-conventional and renewable energy sources.

CO 5: Comprehend the recent advancements in energy generations.

CO 6: Design skills in non-conventional energy systems and enhance written communication.

Syllabus:

Units	Contents	Hrs.
1	**Introduction to energy:** Energy demand growth and supply, Historical perspectives, Fossil fuels: Consumption and Reserves, Environmental impacts of burning fossil fuels, Sustainable development and the role of renewable energy.	6
2	**Wind and Hydro power systems :** Atmospheric circulations, factors influencing the winds, wind turbines and types, coefficient of power, torque, Betz limit, Aerodynamic design principle for blades, Introduction to hydro power plant and types, overview of micro, mini and small hydropower plant, types and operational characteristics of hydro turbine	6
3	**Bio energy and bio-fuels:** Biomass source and characterization, direct combustion, pyrolysis, mechanism of bio-renewable energy, Gasifiers, updraft gasifier, downdraft gasifier, gasifier-based electricity-generating systems, application of biogas slurry in agriculture, bio ethanol for energy generation	6
4	**Fuel cells:** Working principle of fuel cells, fuel cell electrochemistry, types of fuel cells: Alkaline fuel, Fuel Cells, Phosphoric acid fuel cell, Solid oxide fuel cell, Molten carbonate fuel cell, Direct methanol Fuel Cell, their	6

	applications, relative merits and demerits. Introduction to thermal heat storage.	
5	**Tidal energy:** Tidal power plants: single basin & two basin plants, variation in generation level, Ocean thermal electricity conversion, electricity generation from waves, shortline and floating wave systems. **Geothermal energy:** Introduction, Geothermal sites in India, high temperature and low temperature sites in India, Conversion technologies, Steam and binary systems, geothermal power plant, open loop and closed loop system	6
6	**Solar energy:** Principles of solar energy conversion: Photovoltaic (PV) cells and solar thermal systems, Efficiency of solar cells and factors affecting performance, Solar power plants: Concentrated solar power (CSP) vs. photovoltaic systems, Solar thermal collectors and applications, Energy storage for solar power systems,	6

Suggested learning resources:

Text Books :

- Godfrey Boyle, Renewable energy, Oxford press, 2012
- Twidell J and Weir T., Renewable energy resources, Taylor and Francis, 2006
- Rai G.D., Non-conventional energy sources, Khanna Publication, 2009
- B.H. Khan, Non-conventional energy sources, Mcgrawhill education, 2006.
- "Solar energy" by S. P. Sukhatme, Fourth edition, McGraw Hill Education.

Reference Books:

- Wind Energy Systems by Johnson G. L., Prentice Hall,1985
- Introduction to Hydro Energy Systems: Basics, Technology and Operation by Wagner H. and Mathur J, Springer, 2009.
- Bio-fuels: biotechnology, chemistry, and sustainable development by DM Mousdale, CRC Press, 2008.
- Fuel Cells: From Fundamentals to Applications by S Srinivasan, Springer, 2006

NPTEL Course:

https://nptel.ac.in/courses/103103206

PEC-4.10 : Steam and Gas Turbines

Course Code	Course Name	Teaching Scheme (Weightage in Hr.)					Evaluation Scheme (Weightage in %)				
							Theory			Laboratory	
		L	T	P	S	Cr	MSE	TA	ESE	ISE	ESE
<tbd>	Steam and Gas Turbines	3	0	0	1	3	30	20	50	------	

Prerequisites: Engineering Thermodynamics, Fluid Mechanics, Heat Transfer

Course Outcomes (COs):

After learning the course the students should be able to:
CO 1. Analyse thermodynamic cycles of steam power plant and understand construction, working and significance of its various components.
CO 2. Analyse thermodynamic cycles of gas turbine power plant and jet propulsion systems

Syllabus:

Unit	Contents	Hrs.
1	**Steam Nozzles:** Types of nozzles, velocity of steam, discharge through nozzle, critical pressure ratio and condition for maximum discharge, physical significance of critical pressure ratio, nozzle efficiency	6
2	**Steam Turbine:** Principle of operation, types of steam turbines, compounding of steam turbines, impulse turbine - velocity diagram, calculation of work, power and efficiency, condition for maximum efficiency, Reaction turbines - velocity diagram, degree of reaction, reheat factor, governing of steam turbine - throttle, nozzle and bypass governing, Methods of attachment of blades to turbine rotor, Labyrinth packing, Losses in steam turbine, Special types of steam turbine- back pressure, pass out and mixed pressure turbine.	10
3	**Gas Turbine:** Classification, open and closed cycle, gas turbine, fuels, the actual Brayton cycle, optimum pressure ratio for maximum thermal efficiency, work ratio, air rate, effect of operating variables on the thermal efficiency and work ratio, and air rate, simple open cycle turbine with regeneration, reheating and Intercooling, Combined steam and gas turbine plant, requirements of combustion chamber, types of combustion chambers.	10
4	**Jet Propulsion:** Fundamentals of propulsion technology, Turbojet Engine, thrust, thrust power, propulsive efficiency, thermal efficiency, Turboprop, Ramjet and Pulsejet engines	8

Suggested learning resources:

TEXT BOOKS/ REFERENCE BOOKS (Title, Authors, Publisher & Year): -

1. Groover, M. P. - Automation, Production Systems, and Computer-Integrated Manufacturing (Pearson)

2. Tönshoff, H.K., & Denkena, B. - Digital Manufacturing (Springer)
3. Tao, F., Cheng, Y., & Zhang, M. - Digital Twin Driven Smart Manufacturing (Elsevier)
4. Alasdair Gilchrist - Industry 4.0: The Industrial Internet of Things

Reference Books:

1. Power Plant Engineering, P.K. Nag, McGraw-Hill Education
2. Power Plant Engineering, R. K. Hegde, Pearson India Education
3. Gas Turbines, V. Ganeshan, McGraw Hill Education
4. Thermal Engineering, R.K.Rajput, Laxmi Publication
5. Steam Turbine Theory and Practice, William J. Kearton, CBS Publication

List of Open-Source Software/learning websites:

http://nptel.ac.in/courses/112104117/18
http://nptel.ac.in/courses/112104117/4
http://nptel.ac.in/courses/112104117/17

V-5 : MDM II Biomass Processing Technologies

Course Code	Course Name	Teaching Scheme (Weightage in Hr.)					Evaluation Scheme (Weightage in %)				
		L	T	P	S	Cr	Theory			Laboratory	
							MSE	TA	ESE	ISE	ESE
MDM II	Biomass Processing Technologies	3	1	0	0	4	30	20	50	-	-

Course Outcomes:

Students who successfully complete this course will have demonstrated an ability to:

CO 1: Classify different types of biomass, including lignocellulosic materials and bio-based wastes, and their roles in producing energy and chemicals.

CO 2: Describe the principles of biorefineries and the economic aspects of process integration and product options.

CO 3: Understand the processes for producing bioethanol and apply Monod kinetics to optimize fermentation.

CO 4: Assess technologies like gasification and pyrolysis for energy production and resource recovery.

Syllabus:

Unit	Contents	Hrs.
1	**Introduction to Biomass Energy :** Global energy scenario and fossil fuel depletion. Biomass as a renewable energy source. Availability, abundance, and energy potential of biomass. Photosynthesis and energy production. Types of biomass: virgin, waste (municipal, industrial, agricultural, forestry). Energy crops: maize, sorghum, sugarcane, perennial herbaceous crops, woody crops. Microalgae as biofuel feedstock. Challenges in improving biomass for biofuel conversion.	6
2	**Biorefinery Concepts and Feedstocks :** Introduction to biorefineries. Types of biorefineries and their feedstocks. Feedstock properties and selection. Economic aspects of biorefineries. Market demand, production costs, scalability. Case studies on successful biorefineries.	6
3	**Biomass Pretreatment and Conversion Processes :** Challenges in lignocellulosic biomass conversion. Pretreatment methods: acid, alkali, autohydrolysis, hybrid methods. Role of pretreatment in biomass processing. Physical and thermal conversion processes. Equipment, applications, and products. Thermal conversion products: syngas, biooil, biochar. Case studies on successful thermal conversion.	6
4	**Microbial Conversion and Biofuels:** Microbial conversion processes. Biodiesel production from vegetable oils, microalgae, and syngas. Transesterification and biodiesel purification. Bioethanol and biobutanol production. Fermentation technologies and microorganisms. Biohydrogen and biogas production. Fuel cell integration. Biooil and biochar production and upgradation.	6

5	**Organic Commodity Chemicals and Integrated Biorefineries :** Biomass as feedstock for organic chemicals. Production of lactic acid, succinic acid, acetic acid, PHA. Integrated biorefineries: corn, soybean, sugarcane, lignocellulosic, algal. Hybrid chemical and biological conversion processes. Techno-economic evaluation and life-cycle assessment of biorefineries.	8

Useful Learning Resources

Tutorials

1. Overview of biomass energy, including global energy scenarios, biomass types, and their potential as a renewable resource.
2. Introduction to biorefinery concepts, types of feedstocks, economic aspects, and case studies of successful biorefineries.
3. Examination of biomass pretreatment methods, including acid and alkali processes, and their role in improving conversion efficiency.
4. Study of microbial conversion processes for biodiesel, bioethanol, biobutanol, and biohydrogen production, along with fermentation technologies.
5. Exploration of biomass as a feedstock for organic chemicals, including the production of lactic acid, succinic acid, and integrated bio refineries.

Reference Books:

1. "Biomass to Renewable Energy Processes" by Jay Cheng
2. "Biomass Processing Technologies" by Rajesh Kumar Sharma and Sandeep Kumar
3. "The Biorefinery: A Sustainable Approach to the Production of Fuels and Chemicals" by David S. Armenta
4. "Biofuels: Production and Utilization" by S. K. Singh and M. S. Ranjan
5. "Lignocellulosic Biomass for Bioenergy" by R. A. B. D. Bevan

T. Y. B. Tech : Mechanical Engineering
[Level 5.5, UG] Semester -VI

Sr No	Course Type	Course Code	Course Name	L	T	P	S	Cr	Evaluation Scheme (Weightage in %)				
									Theory			Laboratory	
									MSE	TA	ESE	ISE	ESE
1	PCC		Mechanical System Design	3	0	2	1	4	30	20	50	50	50
2	PCC		Computer Aided Design and Manufacturing	3	0	2	1	4	30	20	50	50	50
3	PCC		Fluid Machinery	3	0	2	0	4	30	20	50	50	50
4	PEC		Program Elective Course -II (Specify List) *	3	1	0	0	4	30	20	50	--	--
5	MDM		Multidisciplinary Minor III	3	1	0	1	4	30	20	50	--	--
6	ELC		Project-II	0	0	4	2	2				CIE-100	
Total Credit								22					

Exit Option to B VOC:

Sr. No.	Course Type	Course Code	Course Name	L	T	P	S	Cr	Evaluation Scheme (Weightage in %)				
									Theory			Laboratory	
									MSE	TA	ESE	ISE	ESE
01	PCC		Finite Element Analysis	3	1	0	1	4	30	20	50		
02	PCC		Generative design	3	1	0	1	4	30	20	50		

*Program Elective Course II – Discipline-wise List			
Design Engineering	**Thermal Engineering/Fluid Science**	**Manufacturing Science and Engineering**	**Other Disciplines**
Advanced Finite Element Method (FEM)	Industrial Hydraulics and Pneumatics	Micro & Nano Machining	Biomass Energy Conversion
Design for Fatigue and Fracture	Computational Fluid Dynamics	Digital Manufacturing	Automotive Energy Conversion
Piping Design	Heat Exchangers: Fundamentals and Design Analysis	Micro Fluidics	Deep Learning

VI-1: Mechanical System Design

Course Code	Course Name	Teaching Scheme (Weightage in Hr.)					Evaluation Scheme (Weightage in %)				
							Theory			Laboratory	
		L	T	P	S	Cr	MSE	TA	ESE	ISE	ESE
	Mechanical System Design	3	0	2	1	4	30	20	50	50	50

Course Outcomes (COs):
At the end of the course students will be able to:

CO1: Apply fundamental principles of fatigue and stress concentration while designing various components.

CO2: Design spur, helical, bevel and worm gears.

CO3: Select sliding and rolling contact bearings.

CO4: Explain and select different types of transmission drives.

CO4: Identify different types of vibrations and calculate the natural frequency of various systems.

CO6: Apply the balancing concept to various types of rotating and reciprocating machine elements.

Syllabus:

Unit	Contents	Hrs.
1	**Design against fluctuating load:** Stress concentration, fatigue failure, endurance limit, notch sensitivity, Goodman and Soderberg diagrams, and modified Goodman diagram.	6
2	**Bearings:** Working principle of hydrodynamic, hydrostatic bearing and rolling contact bearing. Classification of bearings. Selection of bearings from manufacturer's catalogue. Comparison of sliding contact and rolling contact bearings.	4
3	**Design of gears:** Terminology, force analysis, gear tooth failures of spur gear, helical gear, bevel gear and worm gear. Design of all above-mentioned types of gears. Methods of lubrication.	10
4	**Friction drives:** Belts, Clutches and Brakes: types, power and torque transmission, and absorption derivations.	6
5	**Balancing:** Static and dynamic balance, balancing of revolving masses on several planes, balancing of reciprocating masses in single and multi cylinder engines, balancing machines.	6
6	**Mechanical vibrations:**	8

	Fundamentals, undamped and damped free vibrations of single degree freedom system, forced vibration of single degree of freedom system, critical speed of shafts.	

Suggested learning resources:

Text Books

1. Bhandari V.B. - "Design of Machine Elements", McGraw Hill Education (India) Ltd.
2. Shigley J.E. and Mischke C.R."Mechanical Engineering Design" McGraw Hill Publ. Co.Ltd.
3. Ballaney, P.L., "Theory if Machines and Mechanisms", 2005, ISBN 9788174091222
4. Hannah and Stephens, "Mechanics of Machines: Advanced Theory and Examples", 1970, ISBN 0713132329 Edward Arnold London

Reference Books

1. Spotts M.F. -"Design of Machine Elements", Prentice HallInternational.
2. Black P.H. and O. Eugene Adams - "Machine Design" - McGraw Hill BookCo.Ltd.
3. "Design Data" - P.S.G. College of Technology,Coimbatore.
4. Hall A.S .; Holowenko A.R. and Laughlin H.G. - "Theory and Problems of Machine Design" - Schaum"s outlineseries.
5. Ulicker Jr. J.J., Penock G.R. & Shigley J.E. "Theory of Machines and Mechanisms" Tata McGraw Hills.
6. Ghosh Amitabha & Mallik Asok Kumar, "Theory of Mechanisms and Machines" east-West Press Pvt. Ltd. New Delhi

Weblinks:

https://archive.nptel.ac.in/courses/112/105/112105125/
https://archive.nptel.ac.in/courses/112/106/112106137/

VI-2 : Computer Aided Design & Manufacturing

Course Code	**Course Name**	**Teaching Scheme (Weightage in Hr.)**					**Evaluation Scheme (Weightage in %)**				
							Theory			**Laboratory**	
		L	**T**	**P**	**S**	**Cr**	MSE	TA	ESE	ISE	ESE
<tbd>	Computer Aided Design & Manufacturing	**3**	**0**	**2**	**1**	**4**	30	20	50	50	50

Course outcomes:
Students who successfully complete this course will have demonstrated an ability to:

CO1: Understand the fundamentals of Geometric modelling

CO2: Develop and manipulate the curves using algebraic, parametric equations

CO3: Develop and manipulate the surfaces using parametric equations

CO4: Develop and manipulate the solid models using different modelling approaches

CO5: Apply various 2-D and 3-D geometric transformations

CO6: Examine CNC program for production of components

Syllabus:

Unit	**Contents**	**Hrs.**
1	Introduction: Definitions, Historical developments. Geometric Modelling, Nameable Un-nameable shapes, Affine and convex combination. Introduction to Equations - Implicit, explicit, parametric. Coordinate systems, Concepts of Torsion and Curvature, Osculating Plane, Binormal Vector. Concepts of Continuity.	**4**
2	Design of Curves: Cubic Hermite curves - Algebraic and geometric forms, Blending functions, Subdivision, Reparameterization, Truncating, Space curve, four point form, straight line and Composite Hermite curves (C^n & G^n continuity). Spline curve, Bezier curves - Control polygons and Bernstein basis, De Casteljau algorithm, First and second derivatives at the ends, Continuity aspects. B-Spline Curves - periodic, open and non-uniform knot vectors and corresponding curves, Rational B-Splines, NURBS.	**8**
3	InDesign of surfaces: Hermite Surface - Algebraic and geometric form, tangent and twist vectors, blending functions, plane surface, cylindrical surface, ruled surface, surface of revolution. Bezier surface - Control net representation, Continuity aspects.	**6**
4	Introduction to Solid Modelling - Topology, Generalized concept of boundary, set theory, Boolean operators (Union, Difference and Intersection).	**8**

	Set memberships classification, Euler and modified form of equations. Solid model construction: Boolean models, Instances and parameterised shapes, sweep, Boundary Representation (B-Rep), Constructive Solid Geometry (CSG), Generative design	
5	Geometric verses coordinate transformations, 2D geometric transformations, Homogeneous coordinate Composite transformations, 3D transformations, Inverse transformations, geometric mapping, Examples of transformation applications in mechanical engineering	**5**
6	Introduction to NC/CNC/DNC machines, Classification of NC systems, Axis nomenclature, Interpolation, features of CNC controllers, Types of CNC machines, Construction features of CNC machines, Manual Part Programming, NC word format, Details of G and M codes, Canned cycles, subroutines and Do loops, Tool radius and length compensations. Exercises on CNC turning center and machining center programming	**6**

Suggested learning resources:

Textbooks:

1. Michael E. Mortenson, Geometric Modeling, John Wiley & Sons; 2nd edition
2. David Rogers, J. Alan Adams, Mathematical Elements for Computer Graphics (GENERAL ENGINEERING), McGraw Hill; 2nd edition.
3. Ibrahim Zeid, R Sivasubramanian, CAD CAM Theory And Practice, Ibrahim Zeid, McGraw Hill Education; 2nd edition
4. Martti Mantyla, Introduction to Solid Modelling, Computer Science Press.

Reference Books:

1. Gerald Farin, Curves and Surfaces for CAGD, Morgan Kaufmann Publishers In; 5th edition
2. Les Piegl (Author), Wayne Tiller, The NURBS Book, Springer-Verlag.

Practical Course Strategy

- Students will be expected to work in teams of two or three.
- Lab-work will be assigned each week. The lab-work will consist of study as well as designing curves & surfaces. Students are expected to complete the homework in teams. However, each student is required to submit his/her homework individually.
- The team will be required to simulate their work on MATLAB or any other coding based platforms. A report showing the detailed calculations and results of representations must be performed for each assigned team.
- Students will be expected to write simple codes (in MATLAB, JULIA, PYTHON, etc.) for specific problem in order to get a better grasp of the material covered in the course.
- Students are expected to participate actively in the course. 5% of the final grade will be based on class participation.
- Some typical design based assignments are provided for students can familiarize themselves with coding environment. The course instructor has the freedom to add on more design and CAM based lab-work as and when required**.

Sr. No.	Practical Lab Work List	COs Mapped

1.	Formation of varying degree curves and studying their nature.	CO1, CO2
2.	Study of Known shapes of curves and modelling them by Algebraic Forms	CO1, CO2
3.	Study of Known shapes of curves and modelling them by Parametric Forms	CO1
4.	Time Study of various parametric forms and algebraic of circle	CO2
5.	Formation of Hermite curves by – a. Varying Magnitude of a single tangent vector in a specified range. a. Varying Magnitude of a both tangent vectors in a specified range. b. Varying Direction Cosines which impact direction of tangent vectors.	CO2
6.	Study of Bezier Curve by – a. Reversal of control points defined a. Formation of close Bezier Curve with desired continuity C^0, C^1 b. Repeating Certain control points – Multiplicity study	CO1, CO2
7.	Coding of B-Spline Curves a. Studying impact by Varying the control points a. Studying impact by Varying Degree of Curve	CO2
8.	Coding for formation of Surfaces a. Ruled Surfaces / Tabulated Surface a. Surface of Revolution (Sphere, Cylindrical, Arbitrary Curve rotated about and axis) b. Bezier Surface	CO3
9.	Construct a Boolean Tree Structure for a given 3d object with all the instances, scaling, rotation performed on the primitives utilized for the formation of object.	CO4
10.	Assignment to check for Affine transformation properties of curves. a. Translation of curves / Known Figure a. Rotation of curves / Known Figure b. Scaling of Curves / Known Figure	CO2, CO5
11.	Generative Design of Knuckle Joint, Bracket or any other component Under Realistic Load Conditions (Fusion 360 or other licensed software oncampus)	CO4
12.	Assignment on CNC Coding for few specific workpieces.	CO6

Weblinks:
https://archive.nptel.ac.in/courses/112/102/112102101/

VI-3 : Fluid Machinery

Course Code	Course Type	Course Name	Teaching Scheme (Weightage in Hr.)					Evaluation Scheme (Weightage in %)				
								Theory			Laboratory	
			L	T	P	S	Cr	MSE	TA	ESE	ISE	CIE
<tbd>	PCC	Fluid Machinery	3	0	2	0	4	30	20	50	50	50

Course Outcomes (COs):
At the end of the course student will be able to:

CO1: Design and evaluate performance of various Turbo Machines.

CO2: Apply laws of fluid mechanics and governing equations for Turbo Machinery.

CO3: Describe working of various components used for hydraulic & pneumatic systems.

CO4: Design various hydraulic and pneumatic systems for industrial applications.

Syllabus

Unit	Contents	Hrs.
1	Impact of Jet: Force of fluid flow in nozzles, inclined plate, fixed and moving vanes, work done, efficiency. Calculation force exerted on series of moving vanes, velocity diagrams & their analysis.	**05**
2	Introduction and classification of hydrodynamic machines. Impulse Turbine: Principle and Construction, Working, velocity triangles, Power, efficiencies, Number of buckets & jets, Non-dimension parameters. Performance characteristics.	**06**
3	Reaction Turbine: Francis & Kaplan Turbines-construction and Working, draft tubes and its efficiency, Velocity diameter & analysis requirement of head & flow. cavitations . concept of unit speed, unit head , specific speed Governing, Performance & Selection . Governing of turbines	**08**
4	**Centrifugal pumps:** Working principles, Construction, Types, Various heads, multistage pumps, Velocity triangles, Minimum starting speed, cavitation, Maximum permissible suction head (MPSH) and Net positive suction head (NPSH). Methods of priming, calculations of efficiencies, Discharge, Blade angles, Head, Power required Impeller dimensions etc. Specific speed and performance characteristics of pumps.	**08**
5	Reciprocating pumps: Working principle, types, Indicator diagram, effect of air vessel, multiple cylinder pumps. Introduction to Air lift pump, hydraulic ram, deep bore well pump, propeller pump submersible pump, Gear pump (restricted to working principle and construction)	**07**
6	Introduction to Fluid power : constructional and working principle of hydraulic and pneumatic circuits. Basic nomenclature, function and symbols of various components used in hydraulic and pneumatic circuits.	**06**

Text Books

1. Modi & Seth, Fluid Mechanics & Fluid Machinery, Standard Book House 2002.
2. R.K.Rajput,A Text book of Fluid Mechanics and Hydraulic Machines, S.Chand Co.Ltd.,2002
3. Jagdish Lal , Hydraulic Machines Including Fluidics, Metropolitian book.
4. Espisito,Fluid Power with Application, Prentice Hall International,1998
5. J.J.Pipenger ,Industrial Hydraulics, McGraw Hill, N.York, 1981.

Reference Books

1. S.R. Majumdar, Pneumatic Systems Principles and Maintenance, Tata McGraw-Hill, N.Delhi, 2000.
2. S.R. Majumdar, Oil Hydraulic Systems and Maintenance, Tata McGraw-Hill, N.Delhi, 2001.
3. ISO-1219:1988 Fluid Systems and Components.
4. Yeaple Franklin, Hydraulics and Pneumatics Power and Control, McGraw Hill Book. Co. N.York, 1966.

Fluid Machinery Laboratory Teaching Scheme Practical: 2 hrs / week	**Examination Scheme** CIE 100 marks

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

- Evaluate performance of hydraulic turbines.
- Evaluate performance of centrifugal pump.
- Describe the construction, working and application of components used in hydraulic and pneumatic circuits.
- Design of various hydraulic and pneumatic circuits.

List of experiments:
The journal consisting of at least seven experiments among the following should be submitted. Two experiments out of first three and the sixth experiment is compulsory.
1. Study and trial on Pelton Turbine for performance testing.
2. Study and trial on Francis Turbine for performance testing.
3. Study and trial on Kaplan Turbine for performance testing.
4. Study & trial on centrifugal pump for performance testing.
5. Study & trial on gear pump for performance testing.
6. Hydraulic and pneumatic circuits for some application
8. Demonstration of working of Hydraulic Press
9. Demonstration of cut sections of various Hydraulic Components.

Weblinks:
https://archive.nptel.ac.in/courses/112/104/112104117/

VI-4-1: Advanced Finite Element Method

Course Code	Course Name	Teaching Scheme (Weightage in Hr.)					Evaluation Scheme (Weightage in %)				
		L	T	P	S	Cr	Theory			Laboratory	
							MSE	TA	ESE	ISE	ESE
<tbd>	Advanced Finite Element Method	**3**	**1**	**0**	**0**	**4**	30	20	50	--	

Course outcomes:
Students who successfully complete this course will have demonstrated an ability to:

CO1: Analyze 3D problems in heat transfer, elasticity, and fluid flow using FEM

CO2: Solve transient and coupled field problems with proper time integration and FEM techniques

CO3: Apply FEM to bending of plates and shells and validate results

CO4: Classify and model various types of non-linearity in FEM

CO5: Solve realistic non-linear FEM problems using robust numerical strategies

CO6: Implement and validate non-linear simulations for real-world problems

Syllabus:

Unit	Contents	Hrs.
1	**3D Finite Element Analysis** Solid elements (tetrahedral, hexahedral), shape functions, numerical integration FEM formulations for physics of 3D heat conduction, elasticity, incompressible materials and viscous flow. Babuska- Brezzi Condition	6
2	**Transient and Coupled Field Problems** Time-dependent FEM (structural dynamics, conduction, convection, diffusion) Coupled thermo-mechanical and multi-physics problems	6
3	**Plate and Shell Bending** Need for a higher order theory, Kirchhoff and Mindlin plate theories, shell element modeling. Applications to aerospace, automotive, and civil systems	8
4	**Introduction to Non-Linear FEA** Geometric, material, and contact non-linearity, Various strain and stress measures for non-linearlity analysis. Conversion of engineering stress -strain curve to True stress strain curve , Johnson-Cook plasticity model, Total and Updated Lagrangian formulations	6
5	**Solving Non-Linear Problems** Non-Linear Bending of Beams, Large deformation, plasticity, hyperelasticity, viscoelasticity, Frictional/contact problems and nonlinear solution algorithms	8
6	**Applications and Case Studies** Simulations in Solvers (ANSYS, Abaqus, etc.): metal forming, crash, biomedical, NVH, Fatigue and Crash Solver settings, mesh convergence, interpretation	8

Suggested learning resources:
Textbooks:

- Introduction to Finite Element Method By J.N .Reddy.
- Cook R.D. “Concepts and applications of finite element analysis” Wiley, New York, 1981.
- Bathe K.J., Cliffs, N.J. “Finite element procedures in Engineering Analysis”, Englewood. Prentice Hall, 1981.
- “Practical Finite Element Analysis”, First Ed., N. Gokhale, S. S. Deshpande, S. V. Bedekar, A. N. Thite, Published By - Finite to Infinite, Pune, India.

Reference Books:

- An Introduction to Nonlinear Finite Element Analysis by J. N. Reddy, Oxford University Press, 2004, ISBN 0198525
- The Finite Element Method: Linear Static and Dynamic Finite Element Analysis by T. J. R. Hughes, Dover Publications, 2000.29X.
- Desai C.S. and J.F. Abel “Introduction to the finite element method.” New York, Van Nostrand Reinhold, 1972.

Practical Course Strategy

- Students will be expected to work in teams of two or three.
- Lab-work will be assigned each week. The Lab-work will consist of mathematical derivations and numerical simulations. Students are expected to complete the homework in teams. However, each student is required to submit his/her homework individually.
- The team will be required to simulate their work on ANSYS or similar licensed solvers. A report showing the detailed calculations and results of simulations performed will be required for each assigned team.
- Students are expected to participate actively in the course. 5% of the final grade will be based on class participation.
- Some typical simulation based assignments are provided for students to get hold of licensed FE solvers. The course instructor has the freedom to add or change lab-work as and when required**.

Suggestive List of Practical / Lab Work**

Practical No.	Title	Linked CO	Objective
1	3D Heat Conduction Analysis in a Cubic Block	CO1	Apply 3D FEM to solve a steady-state thermal conduction problem using brick elements.
2	Structural Analysis of a 3D Bracket under Load	CO1	Analyze 3D elasticity problem with stress-strain evaluation using isoparametric elements.
3	Transient Thermal Response of a Heat Sink	CO2	Model and analyze transient heat conduction in a fin using time-stepping algorithms.
4	Coupled Thermo-Mechanical Analysis of a Bimetallic Strip	CO2	Simulate thermal expansion and stress in a bimetallic structure due to heating.
5	Bending of a Simply Supported Plate	CO3	Use Mindlin plate theory to analyze deflection and bending stresses in a square plate.

Practical No.	Title	Linked CO	Objective
6	Bending of a cantilver beam into a circle	CO4	Understand small and large deformations and associated large rotations .
6	Large Deformation Analysis of a Rubber Seal	CO4	Demonstrate geometric and material non-linearity through hyperelastic modeling.
7	Elasto-Plastic Analysis of a Notched Specimen under Tension	CO5	Analyze non-linear stress-strain behavior and plastic deformation using iterative solvers.
8	Modal and Crash Simulation of a Car FUPD,RUPD System (FUPD : Front Under-run Protection Device and Rear Under run Protection Device)	CO6	Perform NVH modal analysis and crash simulation for energy absorption and failure study.
9	Weld Joint Simulation under Static Loading	CO4, CO5	Model weld geometry, simulate stress concentration and plasticity at the weld zone.
10	Pre-Tensioned Bolt Assembly Analysis	CO4, CO5	Simulate bolt preload using contact and pretension elements, study clamping effects.
11	Rolling Element Bearing Load Distribution	CO1, CO5	Analyze contact forces and deformation in a ball or roller bearing under radial load.
12	Shrink Fit Simulation between Shaft and Hub	CO2, CO5	Model thermal expansion to simulate interference fit; evaluate stress distribution.
13	Low-Cycle Fatigue Analysis Using Strain-Life (ε-N) Approach	CO6	Simulate cyclic loading on a notched component using the strain-life method; account for plastic strain.
14	High-Cycle Fatigue Using Non-Linear Stress-Life (S-N) Curves	CO6	Use non-linear S-N data to predict fatigue life in elastic regime under varying amplitude loading.
15	Weld Fatigue Analysis with Structural Hot Spot Method	CO4, CO6	Evaluate fatigue at weld toe/root using hot spot stress method; ideal for welded beam structures.
16	Multi-Axial Fatigue of a Shaft Under Combined Bending and Torsion	CO6	Apply critical plane-based multi-axial fatigue models to evaluate life under complex stress state.

Weblinks:
https://nptel.ac.in/courses/112106130

VI-4.2 : Industrial Hydraulics and Pneumatics

Course Code	Course Name	Teaching Scheme (Weightage in Hr.)					Evaluation Scheme (Weightage in %)				
		L	T	P	S	Cr	Theory			Laboratory	
							MSE	TA	ESE	ISE	ESE
<tbd>	Industrial Hydraulics and Pneumatics	3	1	0	0	4	30	20	50	--	--

Course Outcomes (COs):
At the end of the course student will be able to:

CO1: Working principle of various components used for hydraulic & pneumatic systems.

CO2: Identify various components of hydraulic & pneumatic systems.

CO3: Ability to select appropriate components required for hydraulic and pneumatic systems.

CO4: Ability to design hydraulic and pneumatic system for industrial applications.

CO5: Ability to understand industrial applications of hydraulic and pneumatic system.

CO6: Troubleshooting of hydraulic & pneumatic circuits

Syllabus:

Unit	Contents	Hrs.
1	**Introduction to Hydraulics and Pneumatics:** Introduction to oil hydraulics and pneumatics, their structure, advantages and limitations. Properties of fluids, Fluids for hydraulic systems, governing laws. Distribution of fluid power, ISO symbols, and energy losses in hydraulic systems.	8
2	**Pumps & Power Units:** Types, classification, principle of working and constructional details of vane pumps, gear pumps, radial and axial plunger pumps, screw pumps, power and efficiency calculations, characteristics curves, selection of pumps for hydraulic Power transmission. **Power units and accessories:** Types of power units, reservoir assembly, constructional details, pressure switches, temperature switches. **Accumulators:** Types, selection/ design procedure, applications of accumulators. Types of Intensifiers, Pressure switches /sensors, Temperature switches/sensors, Level sensors.	8
3	**Hydraulic Actuators:** (i) Linear and Rotary. (ii) Hydraulic motors - Types- Vane, Gear, Piston types, radial piston. (iii)Methods of control of acceleration, deceleration. (iv) Types of cylinders and mountings. (v) Calculation of piston velocity, thrust under static and dynamic applications, considering friction, inertia loads. (vi) Design considerations for cylinders. Cushioning of cylinder. (Numerical treatment).	8
4	**Industrial Circuits:** Simple reciprocating, Regenerative, Speed control (Meter in, Meter out and bleed off), Sequencing, Synchronization, transverse and feed, circuit for riveting machine, automatic reciprocating, fail safe circuit, counter balance	8

	circuit, actuator locking, circuit for hydraulic press, unloading circuit (Numerical treatment), motor breaking circuit.	
5	**Pneumatics:** Principle of Pneumatics: (i) Laws of compression, types of compressors, selection of compressors. (ii) Comparison of Pneumatic with Hydraulic power transmissions. (iii) Types of filters, regulators, lubricators, mufflers, and dryers. (iv) Pressure regulating valves, (v) Direction control valves, two-way, three way, four-way valves. Solenoid operated valves, push button, lever control valves. (vi) Speed regulating Methods used in Pneumatics. (vii) Pneumatic actuators-rotary, reciprocating. (viii) Air motors- radial piston, vane, axial piston (ix) Basic pneumatic circuit, selection of components, (x) Application of pneumatics in low cost automation and in industrial automation. Introduction to vacuum and vacuum measurement, Vacuum pumps, types, introduction to vacuum sensors and valves. Industrial application of vacuum.	6
6	**System Design:** Design of hydraulic/pneumatic circuit for practical application, Selection of different components such as reservoir, various valves, actuators, filters, pumps based on design.	5

Suggested learning resources:

Textbooks:

1. Esposito, Fluid Power with application, Prentice Hall
2. Majumdar S.R, Oil Hydraulic system- Principle and maintenance , Tata McGraw Hill
3. Majumdar S.R, Pneumatics Systems Principles and Maintenance , Tata MeGraw Hill
4. H.L. Stewart, Hydraulics and Pneumatics , Taraporewala Publication GMH1'

Reference Books:

1. J. J. Pipenger, Industrial Hydraulics, MeGraw Hill
2. Pinches, Industrial Fluid Power, Prentice Hall
3. D. A. Pease, Basic Fluid Power, Prentice Hall
4. B. Lall, Oil Hydraulics, International Literature Association
5. Yeaple, Fluid Power Design Handbook
6. Andrew A. Parr, Hydraulics and Pneumatics, Elsevier Science and Technology Books.
7. ISO - 1219, Fluid Systems and components, Graphic Symbols
8. Michael J, Pinches and Ashby J. G, "Power Hydraulics", Prentice Hall.
9. Dr. R.K. Bansal, Fluid Mechanics, Laxmi Publication (P) Ltd.
10. Product Manuals and books from Vickers/ Eaton, FESTO, SMC pneumatics

Weblinks:

https://archive.nptel.ac.in/courses/112/105/112105047/

VI-4.3 : Micro and Nano Machining

Course Code	Course Name	Teaching Scheme (Weightage in Hr.)					Evaluation Scheme (Weightage in %)				
		L	T	P	S	Cr	Theory			Laboratory	
							MSE	TA	ESE	ISE	ESE
<tbd>	**Micro and Nano Machining**	3	1	0	0	4	30	20	50	---	

Course outcomes:

Upon completion of the course, students will be able to:

1. Understand the concept of micromachining and its applications
2. Understand difference between micro and macro machining and importance of non-traditional methods for micromachining
3. Understanding principles and processes of different non-traditional processes for micro machining
4. Understanding principles and processes of mechanical micro machining processes
5. Understanding fundamentals, tools and processes for nanotechnology.
6. Understanding the application of nanotechnology

Syllabus:

Unit	Contents	Hrs.
1	**Introduction to micro machining** Miniaturization, Trend of miniaturization, basic concepts in machining, applications- Bio medical and BioMEMS, watchmaker and jewelry, automotive, aerospace, telecommunication and information technology, Classification of micromachining-Subtractive, additive, mass containing, Joining, MEMS Vs mechanical micromachining, mechanical micromachining Vs ultra precision machining, Operator's skill and sensing in micro machining, things to remember in micro machining **Scaling laws-**Different types of scale reduction of a system, scaling laws, Types of scaling laws, scaling factor	**8**
2	**Difference between macro and micro machining** Size effect in micro cutting- grain size to chip thickness, uncut chip thickness to cutting edge radius, material flow angle of four distinct mechanisms, metal behavior at micro scale machining, failure of ductile, brittle , alloys, anisotropic materials, burr formation-material properties, burr reduction strategies, burr reduction by supporting materials, deburring, Surface roughness- effect of material properties, tool wear, key aspects in micro machining, advantages micro mechanical machining Importance of non-traditional machining in micro machining domain, Classification of Non-traditional Micromachining, Thermal Micromachining, Chemical and Electrochemical Micromachining, Hybrid Micromachining	**8**
3	Introduction to Different Non-traditional Micromachining Processes- Micro Ultrasonic Machining (USM), Micro Electro-Discharge Machining (EDM), Micro Laser Beam Machining (LBM), Micro Ion Beam Machining (IBM), Micro Electron Beam Machining (EBM), Micro Chemical Machining (CM), Micro Electrochemical Machining (ECM), Introduction to Various Hybrid Micromachining- Electrochemical Grinding (ECG), Electrochemical	**8**

	Discharge Micromachining, Abrasive Assisted Micromachining, Ultrasonic Assisted Micromachining, Laser Assisted Micromachining **Mechanical micromachining- Micro tools fabrication and Micro machines** Micro cutting tools, required properties of tool, micro tool fabrication processes **Diamond turning** Need of diamond turning, applications of diamond turning process, classification of diamond turning process, difference with conventional machines, features of Diamond turning machines	
4	**Nanotechnology** Fundamentals behind nanotechnology, tools of nanotechnology- tools for measuring nanostructures-scanning probe instruments, spectroscopy, electrochemistry, electron microscopy and tools to make nanostructures-nanoscale lithography, , dip pen lithography, E-beam lithography, molecular synthesis, nanoscale crystal growth, polymerization, nano bricks and building blocks	**6**
5	**Applications for nanotechnology** Smart materials-self healing structures, recognition, separation, catalysts, heterogeneous nanostructures and composites Sensors- natural nano scale sensors, electromagnetic sensors, biosensors Biomedical applications- drugs delivery, photodynamic therapy, molecular motors	**6**

Textbooks:

1. V K Jain, "Introduction to micromachining", Narosa Publication
2. Balasubramanium et al, "Diamond turn machining: theory and practice (2017)", CRC Press USA
3. Charles P. Poole Jr and Frank J. Owens, "Introduction to Nanotechnology", Wiley-India

Reference Books:

1. Cheng & Huo, "Micro-cutting: Fundamentals and applications", Wiley
2. Dornfeld and Lee, "Precision Manufacturing", Springer
3. Mark Ratner and Daniel Ratner, "Nanotechnology", Pearson Education
4. Lynn E. Foster, "Nanotechnology-Science, Innovation and Opportunity", Pearson Education

Weblinks:

https://archive.nptel.ac.in/courses/117/108/102108078/

VI-4.4 : Biomass Energy Conversion

Course Code	Course Name	Teaching Scheme (Weightage in Hr.)					Evaluation Scheme (Weightage in %)				
							Theory			Laboratory	
		L	T	P	S	Cr	MSE	TA	ESE	ISE	ESE
<tbd>	Biomass Energy Conversion	3	1	0	0	4	30	20	50	--	--

Course Outcomes:

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

CO1: Identify and classify various biomass sources and their energy potential.

CO2: Explain thermochemical and biochemical biomass conversion technologies.

CO3: Design and analyze biomass-based energy systems for thermal and power applications.

CO4: Evaluate the environmental impact and policy frameworks related to biomass energy.

CO5: Investigate real-world biomass utilization projects and propose improvements.

Syllabus:

Unit	Contents	Hrs.
1	**Biomass Resources and Classification:** Overview of biomass: Agricultural residues, forestry waste, energy crops, Properties: Calorific value, moisture content, ash composition, Biomass collection, transportation, preprocessing, densification (briquettes, pellets)	**8**
2	**Thermochemical Conversion Technologies:** Combustion systems and designs, Pyrolysis: Mechanisms, types (slow, fast, flash), Gasification: Fixed bed, fluidized bed, entrained flow Biochar, syngas and bio-oil analysis, Reactor design and efficiency calculations	**7**
3	**Biochemical Conversion Technologies:** Biomass cookstoves, boilers, and dryers, Combined Heat and Power (CHP) from biomass, Co-firing with coal in thermal power plants, Distributed power generation for rural areas	**7**
4	**Biomass Energy Systems and Applications:** Biomass cookstoves, boilers, and dryers, Combined Heat and Power (CHP) from biomass, Co-firing with coal in thermal power plants, Distributed power generation for rural areas	**6**
5	**Environmental and Policy Aspects:** Emissions and pollution control, Carbon neutrality and LCA of biomass systems, Government policies (MNRE schemes, renewable obligations) , Case studies: Bagasse-based plants, rice husk gasifiers, biogas grids	**6**

6	**Integration and Deployment of Deep Learning Models:** Model Deployment Strategies: Edge Computing, Cloud Services, Tools: TensorFlow Lite, ONNX, Docker, Case Studies: Real-world Applications in Mechanical Engineering Ethical Considerations and Model Interpretability	**8**

Reference Books:

1. Thomas B. Reed, Agua Das, "Handbook of Biomass Downdraft Gasifier Engine Systems", NREL
2. Anju Dahiya, "Bioenergy: Biomass to Biofuels", Academic Press.
3. John Twidell, Tony Weir,"Renewable Energy Resources", Taylor & Francis

Weblinks:
https://onlinecourses.nptel.ac.in/noc22_ch28/preview

VI-4.5 : Design for Fatigue and Fracture

Course Code	Course Name	Teaching Scheme (Weightage in Hr.)					Evaluation Scheme (Weightage in %)				
		L	T	P	S	Cr	Theory			Laboratory	
							MSE	TA	ESE	ISE	ESE
<tbd>	Design for Fatigue and Fracture	3	1	0	0	4	30	20	50	--	--

Course Outcomes:

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

CO 1: Understand fatigue mechanisms and design principles under cyclic loads.

CO 2: Apply fatigue failure theories for fluctuating load conditions.

CO 3: Analyze crack formation and growth using fracture mechanics.

CO 4: Estimate component life based on fatigue and crack growth models.

CO 5: Utilize experimental and digital tools for fatigue and fracture analysis.

CO 6: Interpret failures and optimize design using case studies and industrial standards.

Syllabus:

Unit	Contents	Hrs.
1	**Fundamentals of Fatigue** Stress-life (S-N) approach, High-cycle vs Low-cycle fatigue, Fatigue loading types: fully reversed, fluctuating, random, Stress concentration and notch sensitivity, Material fatigue behavior in AM (additive manufacturing) components.	**5**
2	**Design for Fatigue Strength** Mean stress correction theories: Goodman, Soderberg, Gerber Design of components under fluctuating loads, Cumulative damage and Miner's Rule, Influence of surface finish, size, and reliability, AI-based fatigue life prediction, load spectrum analysis	**5**
3	**Fracture Mechanics – Fundamentals:** Modes of fracture: brittle, ductile, Griffith theory of brittle fracture, Fracture toughness, KIC and critical crack length, Introduction to Linear Elastic Fracture Mechanics (LEFM), Fracture in composites and biomaterials	**5**
4	**Crack Propagation and Fatigue Crack Growth** Fatigue crack initiation and growth stages, Paris' law and crack growth rate Threshold stress intensity factor, Life estimation from crack growth data Fracture analysis in layered materials and thin films	**5**

5	**Experimental Techniques and Digital Tools** Fatigue testing machines and methods (rotating beam, axial loading), Fractography (SEM analysis), Digital Image Correlation (DIC), Finite Element Analysis for fatigue and fracture simulation, Machine learning for failure prediction, digital twins in testing	**5**
6	**Case Studies and Modern Applications** Fatigue in gears, shafts, pressure vessels, aircraft structures, Fracture in welded joints and composite structures, Fatigue failure analysis (field failure case studies), Industry standards: ASTM, ISO, ASME, Design-for-durability in EVs, wind turbine blades, biomedical implants	**5**

Reference Books:

1. Suresh, S., Fatigue of Materials, Cambridge University Press
2. Anderson, T.L., Fracture Mechanics: Fundamentals and Applications, CRC Press
3. Juvinall & Marshek, Fundamentals of Machine Component Design, Wiley
4. Dieter, G.E., Mechanical Metallurgy, McGraw-Hill
5. Bannantine, Comer & Handrock, Fundamentals of Metal Fatigue Analysis, Prentice Hall
6. Research papers on fatigue in AM materials, fracture in composites, AI in durability – IEEE, Elsevier

Weblinks:
https://onlinecourses.nptel.ac.in/noc22_mm42/preview

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VI-4.6 : Computational Fluid Dynamics

Course Code	Course Name	Teaching Scheme (Weightage in Hr.)					Evaluation Scheme (Weightage in %)				
		L	T	P	S	Cr	Theory			Laboratory	
							MSE	TA	ESE	ISE	ESE
<tbd>	Computational Fluid Dynamics	3	1	0	0	4	30	20	50	--	--

Course Outcomes:

At the end of the course, students will demonstrate the ability to:

CO 1: Understand the discretization procedure of the governing equations

CO 2: Prepare the problem definition of a given fluid flow heat transfer problem

CO 3: Decide the governing equations, boundary conditions, initial conditions etc for the given problem

CO 4: To carry out the simulations and obtain the results in terms of dependent variables

CO 5: Analyze the CFD results through post processing to obtain engineering parameters

Syllabus:

Unit	Contents	Hrs.
1	**Introduction to CFD:** Computational approach to Fluid Dynamics and its comparison with experimental and analytical methods, Basics of PDE: Elliptic, Parabolic and Hyperbolic Equations.	**6**
2	**Governing Equations:** Review of Navier-Stokes Equation and simplified forms, Solution Methodology: FDM and FVM with special emphasis on FVM, Stability, Convergence and Accuracy.	**7**
3	**Finite Volume Method:** Domain discretizations, types of mesh and quality of mesh, SIMPLE, pressure velocity coupling, Checkerboard pressure field and staggered grid approach	**6**
4	**Geometry Modelling and Grid Generation:** Practical aspects of computational modeling of flow domains, Grid Generation, Types of mesh and selection criteria, Mesh quality, Key parameters and their importance	**7**
5	**Methodology of CFDHT:** Objectives and importance of CFDHT, CFDHT for Diffusion Equation, Convection Equation and Convection-Diffusion Equation	**8**
6	**Solution of N-S Equations for Incompressible Flows:** Semi-Explicit and Semi-Implicit Algorithms for Staggered Grid System and Non Staggered Grid System of N-S Equations for Incompressible Flows	

Suggested learning resources:

References:

1. John A. Anderson, Jr.,Computational Fluid Dynamics, The Basic with applications by John A. Anderson, Jr., McGraw Hill International editions, Mechanical Engineering series.
2. Dr. Suhas Patankar, Numerical Heat Transfer and Fluid Flow, Crc Press.
3. H.K. Versteeg, W.Malalasekera, Introduction to Computational Fluid Dynamics, An: The Finite Volume Method, PHI; 2nd edition.
4. Ferziger and Peric, Computational Methods for Fluid Dynamics, Springer Publication.
5. Chuen-Yen Chow, An Introduction to Computational Fluid Mechanics, Seminole Pub Co.
6. Muralidhar K (Author), Sundararajan, Computational Fluid Flow & Heat Transfer, Narosa Publishing House.

Weblinks:
https://nptel.ac.in/courses/112105045

VI- 4.7 : Digital Manufacturing

<table>
<tr><th rowspan="3">Course Code</th><th rowspan="3">Course Name</th><th colspan="5">Teaching Scheme (Weightage in Hr.)</th><th colspan="5">Evaluation Scheme (Weightage in %)</th></tr>
<tr><th rowspan="2">L</th><th rowspan="2">T</th><th rowspan="2">P</th><th rowspan="2">S</th><th rowspan="2">Cr</th><th colspan="3">Theory</th><th colspan="2">Laboratory</th></tr>
<tr><td>MSE</td><td>TA</td><td>ESE</td><td>ISE</td><td>ESE</td></tr>
<tr><td><tbd></td><td>Digital Manufacturing</td><td>3</td><td>1</td><td>0</td><td>0</td><td>4</td><td>30</td><td>20</td><td>50</td><td>--</td><td>--</td></tr>
</table>

Course Outcomes (COs):
At the end of the course students will be able to:

CO1: Explain the principles and components of digital manufacturing systems.

CO2: Utilize digital tools and technologies for manufacturing applications.

CO3: Analyze manufacturing data to improve processes and product quality.

CO4: Implement digital twins and simulation techniques to applications.

CO5: Understanding the smart manufacturing solutions in various industrial contexts.

CO6: Integrate digital manufacturing tools for manufacturing projects.

Syllabus:

Unit	Contents	Hrs.
1	**Introduction to Digital Manufacturing:** Definition and evolution of digital manufacturing, Key concepts and terminology, Differences between traditional and digital manufacturing, Overview of Industry 4.0	6
2	**Digital Manufacturing Technologies:** Additive Manufacturing (3D Printing), Computer Numerical Control (CNC) Machines, Robotics and Automation, Internet of Things (IoT) in Manufacturing, Cyber-Physical Systems	6
3	**Data Analytics in Manufacturing:** Importance of data in manufacturing, Data collection and management, Big Data Analytics, Predictive Maintenance, Case studies on data-driven manufacturing.	6
4	**Digital Twins and Simulation:** Concept of Digital Twins, Applications of Digital Twins in manufacturing, Simulation techniques and tools, Virtual commissioning of manufacturing systems	6
5	**Smart Manufacturing Systems:** Characteristics of smart manufacturing, Smart factories and their components, Real-time monitoring and control, Role of AI and Machine Learning in Smart Manufacturing	6
6	**Integration and Implementation:** Integration of digital technologies in existing systems, Challenges and solutions in digital manufacturing implementation, Case studies of successful digital manufacturing projects, Future trends and developments.	6

Suggested learning resources:
Text Books

1. Groover, M. P. - Automation, Production Systems, and Computer-Integrated Manufacturing (Pearson)
2. Tönshoff, H.K., & Denkena, B. - Digital Manufacturing (Springer)
3. Tao, F., Cheng, Y., & Zhang, M. - Digital Twin Driven Smart Manufacturing (Elsevier)
4. Alasdair Gilchrist - Industry 4.0: The Industrial Internet of Things

Reference Books:

1. Tien-Chien Chang - Digital Manufacturing: In Design and Production
2. Michael Grieves - Digital Twin: Manufacturing Excellence through Virtual Factory Replication
3. Jay Lee, Behrad Bagheri, & Hung-An Kao - A Cyber-Physical Systems Approach to Smart Manufacturing
4. Sharma, R. & Kundra, T. K. - Introduction to Digital Manufacturing (McGraw-Hill)
5. Kuehn, W. - Digital Factory: Integration of Simulation & Virtual Reality (Springer)
6. Zhang, X. & Tao, F. - Smart Manufacturing: Concepts and Methods (Elsevier)

ONLINE/E RESOURCES:
Related NPTEL/Swayam Courses:
1. Automation in Manufacturing (IIT Kanpur)
2. Computer Integrated Manufacturing (IIT Roorkee)

List of Practicals:
ANY EIGHT experiments to be conducted during the course.

1. 3D Printing Basics: Print simple geometric shapes to understand machine setup, material loading, and basic operation.
2. CNC Machining Introduction: Create a basic part using CNC milling or turning with simple tool paths.
3. Laser Cutting and Engraving: Design and cut/engrave basic shapes or patterns on various materials like wood or acrylic.
4. Basic Robotics Programming: Program a robotic arm to perform simple pick-and-place operations.
5. Simulation of Manufacturing Processes: Use simulation software (e.g., Arena or Simul8) to model a basic production line.
6. IoT in Manufacturing: Set up a simple IoT device to monitor environmental conditions (temperature, humidity) in a manufacturing setup.
7. Digital Twin Creation: Create a digital model of a simple physical object using CAD software and link it to real-time data.
8. Predictive Maintenance: Analyze sensor data to predict and schedule maintenance for a piece of equipment.
9. Virtual Reality (VR) in Manufacturing: Explore a virtual factory setup using basic VR tools and software.
10. Data Analytics for Manufacturing: Use basic statistical tools to analyze production data and identify trends or anomalies.

Weblinks: https://onlinecourses.nptel.ac.in/noc21_mg83/preview

VI- 04.08 : Automotive energy conversion

Course Code	Course Name	Teaching Scheme (Weightage in Hr.)					Evaluation Scheme (Weightage in %)				
		L	T	P	S	Cr	Theory			Laboratory	
							MSE	TA	ESE	ISE	ESE
<tbd>	Automotive energy conversion	3	1	0	0	4	30	20	50	--	--

Course Outcomes:

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

CO 1: Understand the fundamental principles of energy conversion in automotive systems.

CO 2: Analyze various energy conversion devices and their applications in vehicles.

CO 3: Evaluate the efficiency and environmental impact of different automotive energy systems.

CO 4: Explore emerging technologies in automotive energy conversion, including hybrid and electric vehicles.

Syllabus:

Unit	Contents	Hrs.
1	**Internal Combustion Engines and Alternative Fuels:** Thermodynamics and Heat Engines: Principles of thermodynamic cycles, heat engine efficiency, and the conversion of heat into mechanical energy. Spark Ignition (SI) and Compression Ignition (CI) Engines: Comparison of combustion processes, fuel injection systems, and factors affecting efficiency.	**6**
2	**Hybrid and Electric Vehicle Technologies:** Principles of hybrid systems, electric motors, battery technology, and charging systems. Renewable Energy Sources:Exploring the potential of solar and other renewable energy sources for vehicle propulsion.	**7**
3	**Advanced Engine Technologies:** Exploring emerging engine technologies like direct injection, variable valve timing, and advanced combustion strategies. **Fuel Cell Vehicles (FCEVs):** Fuel cell technology, hydrogen storage, and the conversion of chemical energy into electrical energy.	**6**
4	**Fuel Cells and Advanced Energy Storage:** Principles of fuel cell operation and types used in vehicles, Integration of fuel cells into automotive powertrains, Advanced energy storage systems: supercapacitors and flywheels.	**7**
5	**Energy Recovery and Waste Heat Utilization:** Regenerative braking systems: mechanisms and benefits, Waste heat recovery techniques: thermoelectric generators and Rankine cycles, Impact of energy recovery on overall vehicle efficiency.	**8**

Suggested learning resources:

Reference Book:

1. "Fundamentals of Advanced Energy Conversion" by MIT open Course Ware.
2. Jack Erjavec and Rob Thompson, "Automotive Technology: A Systems Approach", Delmar Pub; 7th edition.
3. Mark Warner, The Electric Vehicle Conversion Handbook, HP Books.

4. D. Yogi Goswami, ENERGY CONVERSION 2ED, CRC Press; 2nd edition; TAYLOR & FRANCIS

Weblinks:
https://archive.nptel.ac.in/courses/108/103/108103009/

VI- 4.9 : Course: Piping Design

<table>
<tr><th rowspan="3">Course Code</th><th rowspan="3">Course Name</th><th colspan="5">Teaching Scheme (Weightage in Hr.)</th><th colspan="5">Evaluation Scheme (Weightage in %)</th></tr>
<tr><th rowspan="2">L</th><th rowspan="2">T</th><th rowspan="2">P</th><th rowspan="2">S</th><th rowspan="2">Cr</th><th colspan="3">Theory</th><th colspan="2">Laboratory</th></tr>
<tr><td>MSE</td><td>TA</td><td>ESE</td><td>ISE</td><td>ESE</td></tr>
</table>

<tbd>	Piping Design	3	1	0	0	4	30	20	50	--	--

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

CO1: Understand the safety and practical engineering aspects of piping

CO2: Understand the design and principles used in piping system.

CO3: Know the terminology, concepts, equipment, and process used piping network

CO4: Have an idea of pipe support with other accessories and P& I diagram

Syllabus:

Unit	Contents	Hrs.
1	**Fundamentals of piping:** Classification of pipe, Codes and standards, Pipe Fabrication, vibration, its prevention and control in piping systems, Mechanical Properties of material, schedule number, Piping materials and selection	6
2	**Design calculations for piping** Determination of pipe size, Calculation of pressure drop in pipe, Equivalent length of pipe line for fittings and valves, Energy losses in pipe line, Different types of pumps and their selection criteria, NPSHA & NPSHR, Power required by pump, Calculation of flow measurement in pipe line.	7
3	**Piping component and Flow through pipe line** Types of Fitting, Different types of flange and gasket, their selection criteria and applications, Different types of valves, their selection criteria and applications, Determination of valve size, Steam separators and steam traps, Calculation of pressure drop for two phase flow through pipe line by using Lockhart and Martinelli correlations, Piping drainage and water hammer in process plant, Calculations for water hammer in pipeline.	6
4	**Mechanical design of piping:** Operating pressure and temperature, Design Pressure & Design Temperature for Piping Systems, Design equation for longitudinal, hoop and allowable stresses, Determinations of thickness required by steel pipe for withstanding internal and external pressure, Determinations of thickness required by jacketed steel pipe for withstanding external pressure.	7
5	**Pipe supports and P & I diagram:** Functions of Supports and selection, Types of loads, Different types of piping support, Determination of support location, Maximum span between the supports suggested by ASME B 31.1, Thermal expansion in pipe line, Different types of expansion joints and their applications, Difference between a PFD and P&ID, Typical P&I diagrams for pumps, distillation column, Reactors and Shell and tube heat exchanger.	8

Suggested learning resources:
Reference Book:

Perry R.H., “Chemical Engineers’ Handbook”, McGraw-Hill, 2009.

2 Coulson J.M, Richardson J.F and Sinnott, R.K., “Coulson and Richardson’s Chemical Engineering”, Vol. 6, 4th Edition, Elesevier, Newelhi, 2006.

3 McCabe W.L, Smith J.C, Harriott P., “Unit Operations of Chemical Engineering”, Mc Graw Hill Publication.

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VI- 4.10 : Heat Exchangers: Fundamentals and Design Analysis

Course Code	Course Name	Teaching Scheme (Weightage in Hr.)					Evaluation Scheme (Weightage in %)	
		L	T	P	S	Cr	Theory	Laboratory

							MSE	TA	ESE	ISE	ESE
<tbd>	Heat Exchangers: Fundamentals and Design Analysis	3	1	0	0	4	30	20	50	--	--

Course Outcomes (Cos):

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

CO1: Develop mathematical modeling of various heat exchanger.

CO2: Understand compact heat exchanger

CO3: Design the double pipe heat exchanger and shell & tube heat exchanger.

Syllabus:

Unit	Contents	Hrs.
1	**BASIC DESIGN METHODOLOGIES** Classification of heat exchanger, selection of heat exchanger, Thermal-Hydraulic fundamentals, Overall heat transfer coefficient, LMTD method for heat exchanger analysis for parallel, counter, multipass and cross flow heat exchanger, e-NTU method for heat exchanger analysis, Fouling, Rating and sizing problems, heat exchanger design methodology.	**8**
2	**FOULING OF HEAT EXCHANGERS** Basic consideration, effect of fouling on heat transfer and pressure drop, cost of fouling, design of heat exchangers subject to fouling, fouling resistance, cleanliness factor, techniques to control fouling.	**8**
3	**Piping Design Documentation** Process Flow Diagrams (PFDs): Representation of process systems, symbols, and conventions, Piping and Instrumentation Diagrams (P&IDs): Detailed schematics showing piping, equipment, and instrumentation, Piping Isometrics: 3D representation of piping systems, dimensioning, and annotations, General Arrangement (GA) Drawings: Layout of equipment and piping in a plant, Line Lists and Material Take-Off (MTO): Compilation of piping components and materials required.	**8**
4	**DESIGN OF DOUBLE PIPE HEAT EXCHANGERS** Thermal and Hydraulic design of inner tube and annulus, hairpin heat exchanger with bare and finned inner tube, total pressure drop.	**8**
5	**DESIGN OF SHELL & TUBE HEAT EXCHANGERS** Basic components, basic design procedure of heat exchanger, TEMA code, J-factors, conventional design methods, Bell-Delaware method.	**8**

Reference Books:

1 Heat Exchanger Selection, Rating and Thermal Design by Sadik, Kakac, CRC Press

2 Fundamentals of Heat Exchanger Design by Ramesh K Shah, Wiley Publication

3 Compact Heat Exchangers by Kays, V.A. and London, A.L., McGraw Hill

4 Heat Exchanger Design Handbook by Kuppan, T, Macel Dekker, CRC Press

5 Heat Exchanger Design Handbook by Schunder E.U., Hemisphere Pub.

6 Process Heat transfer by Donald Q Kern, McGraw Hill

Weblinks: https://archive.nptel.ac.in/courses/112/105/112105248/

VI- 4.11 : Micro Fluidics

Course Code	Course Name	Teaching Scheme (Weightage in Hr.)					Evaluation Scheme (Weightage in %)				
		L	T	P	S	Cr	MSE	TA	ESE	ISE	CIE
<tbd>	Micro Fluidics	3	1	0	0	4	30	20	50	-	

Course Outcomes (COs):

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

CO1: Summarize the fundamentals of the physics of flows at micro-scale level.

CO2: Apply a mathematical model for micro scale flow.

CO3: Understand the fundamentals of capillary flow.

CO4: Explain and apply fundamentals of electrokinetics to the flow problems.

CO5: Design components for applications of microfluidics systems.

Syllabus:

Unit	Contents	Hrs.
1	Introduction: Origin, Definition, Benefits, Challenges, Commercial activities,Physics of miniaturization, Scaling laws.	**6**
2	Microscale fluid mechanics: Intermolecular forces, States of matter, Continuum assumption, Governing equations, Constitutive relations. Gas and liquid flows, Boundary conditions, Slip theory, Transition to turbulence, Low Re flows, Entrance effects. Exact solutions, Couette flow, Poiseuille flow, Stokes drag on a sphere, Time-dependent flows, Two-phase flows, Thermal transfer in microchannels.	**8**
3	Capillary flows: Surface tension and interfacial energy, Young-Laplace equation, Contact angle, Capillary length and capillary rise, Lucas-Washburn equation, Interfacial boundary conditions, Marangoni effect	**6**
4	Electrokinetics: Electrohydrodynamics fundamentals, Electro-osmosis, Debye layer, Thin EDL limit, Boltzman ionic distribution, Stokes Einstein equation, Ideal electroosmotic flow, Ideal EOF with back pressure, Osmotic pressure, velocity scale in electroosmosis, Helmholtz-Smoluchowski velocity, Streaming potential, Lenz's Law, Ionic advection, and conduction current, Electroosmotic velocity profile, Electrophoresis of particles, Electrophoretic mobility, Electrophoretic velocity dependence on particle size, Huckel equation	**8**
5	Microfabrication techniques: Materials, Clean room, Silicon crystallography, Miller indices, Oxidation, photolithography- mask, spin coating, exposure and development, Etching, Bulk and Surface micromachining, Wafer bonding, Polymer micro fabrication, PMMA/COC/PDMS substrates, micromolding, hot embossing, fluidic interconnections.	**6**
6	Microfluidics components: Micropumps, Check-valve pumps, Valve-less pumps, Peristaltic pumps, Rotary pumps, Centrifugal pumps, Ultrasonic pump, EHD pump, MHD pumps, Microvalves, Pneumatic valves, Thermopneumatic valves, Thermomechanical valves, Piezoelectric valves, Microflow sensors, Differential pressure flow sensors, Drag force flow sensors, Lift force flow sensors, Thermal flow sensors, Droplet generators, Kinetics of a droplet, Dynamics of a droplet, In-channel dispensers, T-junction and Cross-junction, Droplet formation, breakup and transport.	**6**

Suggested learning resources:
Text Books

1. Nguyen, N. T., Werely, S. T., Fundamentals and applications of Microfluidics, Artech House Inc., 2002.
2. Madou, M. J., Fundamentals of Microfabrication, CRC press, 2002.

Reference Books

1. Bruus, H., Theoretical Microfluidics, Oxford University Press Inc., 2008.
2. Tabeling, P., Introduction to microfluidics, Oxford University Press Inc., 2005.
3. Kirby, B.J., Micro- and Nanoscale Fluid Mechanics: Transport in Microfluidic Devices, Cambridge University Press, 2010.
4. Colin, S., Microfluidics, John Wiley & Sons, 2009.

Weblinks:
https://nptel.ac.in/courses/112105187

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VI- 4.12 : Course: Deep Learning

Course Code	Course Name	Teaching Scheme (Weightage in Hr.)					Evaluation Scheme (Weightage in %)				
		L	T	P	S	Cr	Theory			Laboratory	
							MSE	TA	ESE	ISE	ESE
<tbd>	Deep Learning	3	1	0	0	4	30	20	50	--	--

Course Outcomes:
Students who successfully complete this course will have demonstrated an ability to:

CO 1: Understand the foundational concepts of deep learning.

CO 2: Implement basic neural network architectures.

CO 3: Design and train CNNs for image-based mechanical engineering problems.

CO 4: Develop RNN models for sequential data in mechanical systems.

CO 5: Apply RL algorithms to control problems in mechanical engineering.

Syllabus:

Unit	Contents	Hrs.
1	**Introduction to Deep Learning and Neural Networks:** Overview of Machine Learning and Deep Learning, Biological vs. Artificial Neural Networks, Activation Functions and Loss Functions, Optimization Techniques: Gradient Descent, Backpropagation, Overfitting, Underfitting, and Regularization Methods	**8**
2	**Convolutional Neural Networks (CNNs) for Mechanical Applications:** Convolution Operations and Pooling Layers, Architectures: LeNet, AlexNet, VGG, ResNetTransfer Learning and Fine-Tuning, Applications: Defect Detection, Thermal Imaging Analysis	**7**
3	**Recurrent Neural Networks (RNNs) and Time-Series Analysis:** RNN Architectures: Vanilla RNNs, LSTM, GRU, Sequence Modeling and Prediction, Applications: Vibration Analysis, Predictive Maintenance, Challenges: Vanishing/Exploding Gradients, Sequence Length Handling	**7**
4	**Autoencoders and Generative Models:** Autoencoders: Structure and Training, Variational Autoencoders (VAEs), Generative Adversarial Networks (GANs), Applications: Design Optimization, Anomaly Detection	**6**
5	**Reinforcement Learning in Mechanical Systems:** Fundamentals of Reinforcement Learning (RL),Deep Q-Networks (DQN) and Policy Gradient Methods, Applications: Robotics Control, Adaptive Systems, Simulation Environments: OpenAI Gym, Custom Simulators	**6**
6	**Integration and Deployment of Deep Learning Models:** Model Deployment Strategies: Edge Computing, Cloud Services, Tools: TensorFlow Lite, ONNX, Docker, Case Studies: Real-world Applications in Mechanical Engineering Ethical Considerations and Model Interpretability	**8**

Suggested learning resources:
Textbooks:

1. Aurélien Géron, Hands-On Machine Learning with Scikit-Learn and TensorFlow Concepts, Tools, and Techniques to Build Intelligent Systems, O'Reilly Media, Inc., 1005 Gravenstein Highway North, Sebastopol, CA 95472.

2. Ian Goodfellow, Yoshua Bengio, Aaron Courville, Deep Learning, MIT Press

3. Charu C. Aggarwal , Neural Networks and Deep Learning, Springer Nature.

4. François Chollet , Deep Learning with Python, Manning; First Edition

Weblinks:
https://onlinecourses.nptel.ac.in/noc20_cs62/preview

VI-05- Advances in Farm Equipment and Food Technology

Course Code	Course Name	Teaching Scheme (Weightage in Hr.)					Evaluation Scheme (Weightage in %)				
		L	T	P	S	Cr	Theory			Laboratory	
							MSE	TA	ESE	ISE	ESE

MDM III	Advances in Farm Equipment and Food Technology	3	1	0	1	4	30	20	50	–

Course Outcomes:

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

1. Understand the importance of Farm Machinery and its implementation in context of India.
2. Study the need and implements of Ploughing and its implements.
3. Comprehend various Methods and Equipment of Seeding and Planting.
4. Learn about different methods of crop Protection and Harvesting.
5. Develop understanding of food processing and preservation techniques

Syllabus:

Unit	Contents	Hrs.
1	**Introduction to farm machinery:** Modern trends, principles, procedures, fundamentals and economic considerations of Farm machinery, Importance of farm machinery in the contest of enhanced production, multiple cropping, labour scarcity	**6**
2	**Primary and Secondary Tillage implements:** Definition and Objectives of Tillage, Primary and Secondary Tillage, Physical, Chemical and Biological Influences of Tillage, Concept of ploughing, Tools used for ploughing, Disc Ploughs, Harrows, Seedbed preparation and irrigation	**8**
3	**Seeding and Planting Machines:** Methods of Seeding and Planting and their Mechanization, Tools and Implements for Intercultural Operations, Drills, Planters, Seed and Fertilizer Metering Devices	**7**
4	**Crop Protection and Harvesting:** Objectives and Types of Spraying and Dusting, Working Principle and Components of Sprayers and Dusters, Safety in Handling Plant Protection Machines, Machinery for transport and material handling, Crop Harvesting Methods and their Mechanization, Mowers, Reapers and Windrowers, Pickers and Stripers, Root crop harvesting machinery	**8**
5	**Food processing technology:** General aspects of food industry, world food demand and Indian scenario, quality and nutritive aspects, Food additives, Food additives, Preliminary food processing methods, thermal processing of foods, Steam generation, Fuel utilization, Electric Power Utilization, Process Controls in Food Processing	**7**
6	**Introduction to food preservation:** Objectives and techniques of food preservation, Canning, Preservation principle of canning of food items, Drying techniques, Low temperature food preservation, cold storage, freezing of food products, cryogenic freezing, Preservation by fermentation, Non-thermal and minimal processing technologies, Use of preservatives in foods, packaging of food.	**6**

Useful Learning Resources

Tutorials

1. Study of Different Farm Operations and Familiarization with Farm Machines and Equipment.
2. Study of Power Requirement of Farm Machines and Equipments.

3. Visit to Agriculture farm site to explore various types of Farm machinery.
4. Case study to understand food preservation in case of milk products/beverages/poultry farm products/meat

Text Books:

1. Bernacki C, Haman J &Kanafajski CZ.1972. Agricultural Machines, Oxford & IBH
2. Arthur W Judge 1967. High Speed Diesel Engines, Chapman & Hall
3. Boson ES, Verniaev OV & Sultan-Shakh EG. 1990. Theory, Construction and Calculations of Agricultural Machinery Vol. I. Scientific publishers (India).
4. Food Processing Technology: Principles and Practice (Woodhead Publishing Series in Food Science, Technology and Nutrition), Third addition, June 2009 by P.J. Fellows

Weblinks:

http://www.digimat.in/nptel/courses/video/126105009/L01.html

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Proposed I

Integrated Project-Based Learning and Evaluation Framework (5th, 6th, and 7th Semester)

Summary:

The Progressive Integrated Project Work Articulation and Evaluation Framework at COEP Technological University provides undergraduate engineering students a structured, continuous, and immersive project-based learning experience across the 5th, 6th, and 7th semesters. This framework focuses on long-term engagement with a single engineering problem, enhancing technical expertise, problem-solving, and project management skills. The three-phase approach covers Problem Definition & Feasibility (5th semester), Design & Implementation (6th semester), and Final Implementation & Evaluation (7th semester).

The framework aligns with outcome-based education (OBE) best practices and fosters innovation, research, and entrepreneurship.

Introduction

The Proposed Progressive integrated Project Work Articulation and Evaluation Framework at COEP Technological University is designed to provide undergraduate engineering students with a structured, continuous, and immersive project-based learning experience across the 5th, 6th, and 7th semesters of their academic program. This progressive project model emphasizes long-term engagement on a single, meaningful engineering problem, allowing students to evolve their technical expertise, problem-solving capabilities, and project management skills in a systematic manner.

The framework introduces a three-phased approach — starting from Problem Definition & Feasibility (5th semester), progressing to Design & Implementation (6th semester), and culminating in Final Implementation & Evaluation (7th semester). Through this progression, student teams remain consistent, enabling deep collaboration and sustained focus on their project objectives over multiple semesters.

The model is aligned with national and international best practices in outcome-based education (OBE) and is intended to mirror the iterative, long-duration nature of real-world engineering projects encountered in industry and research. This articulation encourages innovation, research output (including paper publications and patent filings), and entrepreneurial thinking.

A robust evaluation mechanism is embedded within each semester, involving multiple review stages, comprehensive rubrics, and clear deliverables — ensuring continuous assessment of both technical competencies and soft skills like teamwork, communication, and project management. The cumulative project work carries a total of 9 credits, distributed across the three semesters, reflecting its academic rigor and importance.

This document details the semester-wise course outcomes, deliverables, evaluation rubrics, and guidelines to ensure smooth implementation and fair assessment, thereby fostering a rich, application-oriented learning environment at COEP Technological University.

Key Features of the Progressive Project Work

• Continuous project across 5th to 7th semesters with the same student group

• Project topic finalized in the 5th semester

• Progressive development: Micro (5th Sem) → Mini (6th Sem) → Capstone (7th Sem) with total 9 credits (2 + 2 + 5) distribution.

Semester-wise Project Deliverables and Credits

Semester	Course Name	Focus	Deliverables	Credits
5th	Project Phase I	Problem Definition & Feasibility	Project Proposal, Literature Review Report, Feasibility Report, Initial Demo	2

6th	Project Phase II	Design & Implementation	System Design Document, Intermediate Implementation, Progress Report, Demo	2
7th	Project Phase III	Final Implementation & Evaluation	Final Report, Working Project Demo, Viva, Optional: Research Paper/Patent	5

Total project credits = 9 credits (2 + 2 + 5)

• Project Evaluation guidelines: Two evaluations per semester (Progress Mid Sem Review and End Sem Final Review). Marks can be averaged or weighted as per your department's scheme. Mid-Semester will focus on progress, functionality, design, and teamwork. And End-Semester will deep dive into system implementation, testing, documentation, and final presentation quality. Also Comprehensive understanding, clear communication, technical knowledge, and ability to defend the project.

- Final Evaluation Calculation for the Semester: Individual Student-Teacher Assessment Marks (20%), Mid-Semester Marks (30%) and End-of-Semester Marks (50%)

Advantages of This Model

1. Continuity → Deeper understanding of the problem and solution evolution
2. Industry Relevance → Mimics real-world long-term projects
3. Research / Innovation Focus → Encourages paper publication, patents, entrepreneurship
4. Efficient Teaming → No reshuffling; stable collaboration dynamics

First, just to be clear, the NBA **12 Program Outcomes** (POs) are generally:

PO#	Program Outcome
PO1	Engineering knowledge
PO2	Problem analysis
PO3	Design/development of solutions
PO4	Conduct investigations of complex problems
PO5	Modern tool usage
PO6	The engineer and society
PO7	Environment and sustainability
PO8	Ethics
PO9	Individual and team work
PO10	Communication
PO11	Project management and finance
PO12	Life-long learning

PSO#	Program Specific Outcome
PSO1	Apply domain knowledge to solve complex engineering problems.
PSO2	Design and develop efficient solutions using modern tools and techniques.
PSO3	Demonstrate communication, teamwork, and project management skills in professional practice.

5th Semester — Project Phase I (Problem Definition & Feasibility)

1. **Course Outcomes (COs)**

CO1: Identify and define a relevant engineering problem

CO2: Conduct literature review and feasibility analysis

CO3: Develop an initial proof-of-concept/prototype

CO4: Prepare and present project proposal and literature report

Rationale (in brief)

- **PO1–PO4 (Technical Core)** → Strong across all COs because it's a project phase with problem-solving and prototyping.
- **PO5 (Tool usage)** → Moderate to strong for CO2 & CO3 (feasibility + prototype).
- **PO6–PO7 (Society & Sustainability)** → Minimal but considered (ethics/societal relevance of project definition).
- **PO8 (Ethics)** → Light link when defining problem & literature review (plagiarism, citation, responsible innovation).
- **PO9–PO11 (Soft skills, Communication, Management)** → Especially strong in CO4 (proposal writing + teamwork).
- **PO12 (Lifelong learning)** → Moderate in all — students learn how to independently research and adapt.

2. **Articulation Matrix (CO–PO)**

COs / POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1: Identify and define a relevant engineering problem	3	3	2	2	1	1	1	1	2	2	1	2
CO2: Conduct literature review and feasibility analysis	3	3	2	3	2	1	1	1	2	2	1	2
CO3: Develop an initial proof-of-concept/prototype	3	3	3	3	3	1	1	1	2	2	2	2
CO4: Prepare and present project proposal and literature report	2	2	2	2	2	1	1	2	3	3	2	2

(Scale: 3 – Strong; 2 – Moderate; 1 – Low contribution; blank – No contribution)

Now, based on your COs, here's the CO–PSO Mapping Table:

COs / PSOs	PSO1	PSO2	PSO3
CO1: Identify and define a relevant engineering problem	3	2	2
CO2: Conduct literature review and feasibility analysis	3	2	2
CO3: Develop an initial proof-of-concept/prototype	2	3	2
CO4: Prepare and present project proposal and literature report	2	2	3

(Scale: 3 – Strong; 2 – Moderate; 1 – Low contribution; blank – No contribution)

Justification Table for CO–PO–PSO Mapping (for NBA SAR Annexure)

CO	Justification of PO and PSO Mappings
CO1	Strongly aligned with PO1 & PO2 (problem identification & analysis). PO3 & PO4 moderately linked (preliminary solution framework). PSO1 strongly relevant (domain knowledge application). Communication and teamwork moderately engaged (PO9, PO10, PSO3).
CO2	Strongly supports PO1, PO2, PO4 (literature review, feasibility). PO5 moderately linked (tools usage for analysis). PSO1 strong (domain knowledge), PSO2 moderate (tool knowledge). Collaboration (PO9), ethics (PO8) lightly considered.
CO3	Strongest contribution to PO3, PO4, PO5 (prototype development, modern tools). PSO2 strongest here. PO1, PO2 remain high (design based on knowledge/analysis). Moderate teamwork and project management relevance (PO9, PO11).
CO4	Strongly maps to PO9, PO10 (teamwork, communication), PO11 (project management). PSO3 strongest (professional practice). PO5 moderate (tools for documentation/presentation). PO1-PO4 moderate for synthesizing final reports.

3. **Evaluation**

[Team Details]

- **Project Title: ___________________________**
- **Team Members: ___________________________**
- **Guide Name: ___________________________**

Individual Student-Teacher Assessment (20% Weightage)

Component	Marks Range	Marks Awarded	Remar
Individual Contribution: Effort, initiative, and leadership in the project	0–10		
Team Collaboration: Effective teamwork, contribution to group tasks	0–5		
Communication Skills: Individual's communication, presentation, and technical understanding	0–5		
Total Marks (Individual Assessment)	**20 Marks**		
Weighted Marks (20%)			**20 × 0.20 4 Marks**

Signature of Guide: ____________________ **Signature of Evaluator: ______________________**

Date of Evaluation: ______________________

Mid-Semester Evaluation Sheet (30% Weightage)

Component	Marks Range	Marks Awarded	Remark
Problem Definition: Clarity of problem statement, alignment with real-world needs	0–5		
Literature Survey: Depth, relevance, and thoroughness of literature reviewed, practicality of proposed solution	0–5		
Feasibility Study: Quality of feasibility analysis	0–5		
Prototype/PoC: Basic working model demonstrating the approach, technical demonstration	0–5		
Progress in Teamwork: Collaboration, task division, adherence to timelines	0–5		
Communication & Presentation: Clear explanation, structured presentation, Q&A handling	0–5		

Component	Marks Range	Marks Awarded	Remark
Project Review Focus: Progress, functionality, design, teamwork	0–5		
Total Marks (Mid-Semester)	**30 Marks**		
Weighted Marks (30%)			**30 × 0.30 = 9 Marks**

Signature of Guide: ______________________ **Signature of Evaluator:** ______________________

Date of Evaluation: ______________________

End-of-Semester Evaluation Sheet (50% Weightage)

Component	Marks Range	Marks Awarded	Remark
Problem Definition & Objectives: Clarity of problem statement and objectives, well-defined goals	0–10		
Literature Survey & Feasibility: Depth and quality of literature search and feasibility analysis	0–10		
Initial Prototype (PoC): Technical accuracy, functionality of prototype or demonstration	0–15		
Documentation (Proposal): Structure, completeness, quality of the proposal	0–10		
Presentation & Viva: Presentation clarity, responsiveness to questions, demonstration of knowledge	0–15		
Internal Assessment Focus: System implementation, testing, documentation, and final presentation quality	0–10		
Total Marks (End-Semester)	**60 Marks**		
Weighted Marks (50%)			**60 × 0.50 = 30 Marks**

Signature of Guide: ______________________ **Signature of Evaluator:** ______________________

Date of Evaluation: ______________________

6th Semester — Project Phase II (Design & Implementation)

1. **Course Outcomes (COs)**

CO1-6: Design detailed system architecture and specifications

CO2-6: Implement and test core modules

CO3-6: Integrate components into a working system

CO4-6: Document design and development progress

2. **Articulation Matrix (CO–PO)**

COs / POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1: (Design	3	3	2	2	1	1	1	1	2	2	1	2
CO2: Implement & Test)	3	3	2	3	2	1	1	1	2	2	1	2
CO3: (Integrate System)	3	3	3	3	3	1	1	1	2	2	2	2
CO4: Documentation)	2	2	2	2	2	1	1	2	3	3	2	2

Explanation Highlights:

- **CO1-6** aligns best with **PO1, PO2, PO3, and PSO1**, as it involves high-level design and application of domain knowledge.
- **CO2-6** and **CO3-6** are strong on **technical execution**, **tool use (PO5)**, and **system integration**, which ties into **PSO2**.
- **CO4-6** is strongly aligned with **PO9, PO10, PO11, and PSO3**, reflecting the importance of **communication, documentation, and teamwork**.
- **Ethics (PO8)** and **Sustainability (PO7)** are only slightly addressed unless the specific project focuses on these aspects.

CO–PSO Mapping Table

Course Outcomes (COs)	**PSO1 *(Apply domain knowledge)***	**PSO2 *(Design & tools)***	**PSO3 *(Teamwork & communication)***
CO1-6: Design detailed system architecture and specifications	3	2	2
CO2-6: Implement and test core modules	3	3	2
CO3-6: Integrate components into a working system	3	3	3

Course Outcomes (COs)	PSO1 *(Apply domain knowledge)*	PSO2 *(Design & tools)*	PSO3 *(Teamwork & communication)*
CO4-6: Document design and development progress	2	2	3

📌 **Legend:**

- **3** = Strong correlation
- **2** = Moderate correlation
- **1** = Slight correlation
- Blank = No significant correlation

Summary:

- **PSO1 (Domain Knowledge)**: Strongly reflected in **CO1–CO3**, as students apply core mechanical engineering principles.
- **PSO2 (Design & Tools)**: Key in **CO2** and **CO3**, where implementation and integration require modern engineering tools.
- **PSO3 (Communication & Teamwork)**: Most relevant to **CO3** and especially **CO4**, where collaboration and documentation are emphasized.

3. **Evaluation**

[Team Details]

- **Project Title:** ______________________________
- **Team Members:** ______________________________
- **Guide Name:** ______________________________

Individual Student-Teacher Assessment (20% Weightage)

Component	Marks Range	Marks Awarded	Remark
Individual Contribution: Effort, initiative, and leadership in the project	0–10		
Team Collaboration: Effective teamwork, contribution to group tasks	0–5		
Communication Skills: Individual's communication, presentation, and technical understanding	0–5		
Total Marks (Individual Assessment)	**20 Marks**		

Component	Marks Range	Marks Awarded	Remark
Weighted Marks (20%)			**20 × 0.20 = 4 Marks**

Signature of Guide: ______________________ **Signature of Evaluator:** ______________________
Date of Evaluation: ______________________

Mid-Semester Evaluation Sheet (30% Weightage)

Component	Marks Range	Marks Awarded	Remark
System Design: Architecture, UML, Specifications	0–5		
Module Implementation & Testing: Functional modules, efficiency, test cases developed	0–5		
Intermediate Prototype Integration: Quality of intermediate prototype integration, functionality check	0–5		
Team Progress & Collaboration: Task division, timeline adherence, collaborative approach	0–5		
Communication & Presentation: Clarity of explanation, structured demo, handling of questions	0–5		
Project Review Focus: Progress, functionality, design, teamwork	0–5		
Total Marks (Mid-Semester)	**30 Marks**		
Weighted Marks (30%)			**30 × 0.30 = 9 Marks**

Signature of Guide: ______________________ **Signature of Evaluator:** ______________________
Date of Evaluation: ______________________

End-of-Semester Evaluation Sheet (50% Weightage)

Component	Marks Range	Marks Awarded	Remark
System Design (Architecture): Clear, robust system design; architecture diagrams; component-level breakdown	0–10		
Module Implementation: Accuracy, functionality, testing of individual modules	0–15		
Integration & Intermediate Prototype: Integration of subsystems, working prototype	0–10		
Documentation (Design, Progress Report): Comprehensive, structured, and clear documentation	0–10		
Presentation & Viva: Quality of demo, technical explanation, Q&A responses	0–15		
Internal Assessment Focus: System implementation, testing, documentation, and final presentation quality	0–10		
Total Marks (End-Semester)	**60 Marks**		
Weighted Marks (50%)			**60 × 0.50 = 30 Marks**

Signature of Guide: ____________________ **Signature of Evaluator: ____________________**

Date of Evaluation: _____________________

7th Semester — Project Phase III (Final Implementation & Evaluation)

1. **Course Outcomes (COs)**

CO1-7: Complete full implementation, integration, validation

CO2-7: Apply project management, ethics, teamwork

CO3-7: Prepare and defend comprehensive project report

CO4-7: Communicate project outcomes effectively (presentation, demo)

2. **Articulation Matrix (CO–PO)**

Final CO–PO–PSO Mapping Table

COs / Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1-7Complete implementation, integration, validation	3	3	3	3	2	2	1	1	2	2	2	2	3	3	2
CO2-7Project management, ethics, teamwork	2	2	2	2	3	3	1	3	3	3	3	2	2	2	3
CO3-7Report preparation and defense	2	2	2	2	2	3	1	2	3	3	2	2	2	2	3
CO4-7Effective communication and demo	2	2	2	2	2	3	1	2	3	3	2	2	2	2	3

- **CO1-7**: Strong focus on **technical competence**, aligning with **PO1–PO4** and **PSO1/PSO2**.
- **CO2-7**: Emphasizes **ethics, team dynamics, and management**, linking it closely with **PO6, PO8, PO9, PO11**, and **PSO3**.
- **CO3-7** and **CO4-7**: Deal with **documentation, presentation, and communication**, hence strongly mapped to **PO10**, **PO9**, and **PSO3**.

3. **Evalaution**

[Team Details]

- **Project Title:** ____________________________
- **Team Members:** ____________________________
- **Guide Name:** ____________________________

Individual Student-Teacher Assessment (20% Weightage)

Component	Marks Range	Marks Awarded	Remark
Individual Contribution: Effort, initiative, and leadership in the project	0–10		
Team Collaboration: Effective teamwork, contribution to group tasks	0–5		
Communication Skills: Individual's communication, presentation, and technical understanding	0–5		
Total Marks (Individual Assessment)	**20 Marks**		
Weighted Marks (20%)			**20 × 0.20 = 4 Marks**

Signature of Guide: ____________________ **Signature of Evaluator:** ______________________

Date of Evaluation: _____________________

Mid-Semester Evaluation Sheet (30% Weightage)

Component	Marks Range	Marks Awarded	Remark
Final Implementation: Full functionality, completeness, integration of components	0–10		
Testing, Validation, & Performance: Test results, validation against problem statement, performance metrics	0–10		
Team Collaboration & Task Completion: Adherence to timelines, task division, collaboration quality	0–5		
Progress in Documentation: Quality of the final report, documentation of milestones	0–5		
Communication & Presentation: Demo quality, clarity in technical explanation	0–5		
Project Review Focus: Final implementation, testing, validation, teamwork	0–5		
Total Marks (Mid-Semester)	**30 Marks**		
Weighted Marks (30%)			**30 × 0.30 = 9 Marks**

Signature of Guide: _____________________ **Signature of Evaluator:** ______________________

Date of Evaluation: _____________________

End-of-Semester Evaluation Sheet (50% Weightage)

Component	Marks Range	Marks Awarded	Remark
Final Implementation & Integration: Complete and integrated system, adherence to problem objectives	0–20		
Testing & Validation: Thorough testing, validation results, performance analysis	0–15		

Component	Marks Range	Marks Awarded	Remark
Project Management & Teamwork: Planning, resource management, teamwork throughout the semester	0–10		
Documentation (Final Report, User Manual): Final report quality, clarity, technical depth, user manual quality	0–10		
Final Presentation & Viva: Presentation clarity, demo quality, technical and non-technical explanations	0–15		
Internal Assessment Focus: Final implementation, testing, documentation, final presentation quality	0–10		
Total Marks (End-Semester)	**70 Marks**		
Weighted Marks (50%)			**70 × 0.50 = 35 Marks**

Signature of Guide: ______________________ **Signature of Evaluator: ______________________**

Date of Evaluation: ______________________

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VI-Exit Option-01- Finite Element Analysis

Course Code	Course Name	Teaching Scheme (Weightage in Hr.)					Evaluation Scheme (Weightage in %)				
							Theory			Laboratory	
		L	T	P	S	Cr	MSE	TA	ESE	ISE	ESE
tbd	Finite Element Analysis	3	1	0	1	4	30	20	50		

Course Outcomes:

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

1. Understand the different techniques used to solve mechanical engineering problems.
2. Derive and use 1-D and 2-D element stiffness matrices and load vectors from various methods to solve for displacements and stresses.
3. Apply mechanics of materials and machine design topics to provide preliminary results used for testing the reasonableness of finite element results.
4. Solve complex problems in solid mechanics, vibrations and heat transfer.

Syllabus:

Unit	Contents	Hrs.
1	**Fundamental Concepts of FEA** Introduction: Solution methodologies to solve engineering problems, governing equations, mathematical modelling of field problems in engineering, discrete and continuous models. Brief history of FEM, Finite Element terminology (nodes, elements, domain, continuum, degrees of freedom, loads & constraints), general steps involved in FEM, applications of FEM in various fields, advantages and disadvantages of FEM, consistent units system, essential and natural boundary conditions, symmetric boundary conditions. Introduction to different approaches used in FEA : Direct approach, Variational formulation- Principal of Minimum Potential Energy (PMPE), Galerkin weighted residual method, Principle of Virtual Work, Rayleigh-Ritz method, relation between FEM and Rayleigh-Ritz method Types of Analysis (Introduction) : Linear static analysis, Non-linear analysis, Dynamic analysis, Linear buckling analysis, Thermal analysis, Fatigue analysis, Crash analysis.	6
2	**1D Elements** Types of 1D elements, displacement function, global and local coordinate systems, polynomial form of interpolation functions- linear, quadratic and cubic, properties of shape function, primary and secondary variables. Formulation of elemental stiffness matrix and load vector for bar, truss and beam using any approach, Formulation of load vector due to uniform temperature change (only for bar).	6

	Assembly of global stiffness matrix and load vector, properties of stiffness matrix, half bandwidth, treatment of boundary conditions- elimination approach, stress and reaction forces calculations.	
3	**2D Elements** Two-Dimensional Stress Analysis: Plane Stress/Strain problems in 2D elasticity, constitutive relations Constant Strain Triangle (CST), Liner Strain Rectangle (LSR), displacement function, Pascal's triangle, compatibility and completeness requirement, geometric isotropy, convergence requirements, strain filed, stress filed, Formulation of element stiffness matrix and load vector for Plane Stress/Strain problems Assembly of global stiffness matrix and load vector, Boundary conditions, solving for primary variables (displacement), stress calculations	**6**
4	**Isoparametric Elements and Numerical Integration** Concept of isoparametric elements, Terms isoparametric, super parametric and subparametric. Coordinate mapping: Natural coordinates, Area coordinates (for triangular elements), higher order triangular and quadrilateral elements (Lagrangean and serendipity elements), geometry associative mesh, quality checks, mesh refinement- p vs h refinements, Uniqueness of mapping - Jacobian matrix. Numerical integration: Gauss Quadrature in one and two dimensions, Order of Gauss integration, full and reduced integration, sub-modeling, substructuring.	**6**
5	**1D Steady State Heat Transfer Problems** Introduction, One dimensional steady-state heat transfer problem- Governing differential equation, Finite Element formulation using Galerkin's approach for composite wall and thin Fin , essential and natural boundary conditions and solving for temperature distribution	**6**
6	**Dynamic Analysis** Types of dynamic analysis, general dynamic equation of motion, lumped and consistent mass, Mass matrices formulation of bar, truss and beam element. Undamped-free vibration: Eigenvalue problem, evaluation of eigenvalues and eigenvectors (characteristic polynomial technique).	**6**

Useful Learning Resources
Textbooks

1. Daryl L, A First Course in the Finite Element Method. Logan, 2007.
2. Chandrupatla T. R. and Belegunda A. D., Introduction to Finite Elements in Engineering, Prentice Hall India, 2002.
3. Y.M.Desai, T.I.Eldho and A.H.Shah, Finite Element Method with Applications in Engineering, Pearson Education, 2011
4. P., Seshu, Text book of Finite Element Analysis, PHI Learning Private Ltd. , New Delhi, 2010.

Reference Books:

1. Bathe K. J., Finite Element Procedures Prentice, Hall of India (P) Ltd., New Delhi.
2. R. D. Cook, et al., Concepts and Applications of Finite Element Analysis. Wiley, India

3. David V. Hutton, Fundamental of Finite Element Analysis, Tata McGraw-Hill
4. Gokhale N. S., et al., Practical Finite Element Analysis, Finite to Infinite, Pune, 2008.

Weblinks:
https://onlinecourses.nptel.ac.in/noc22_me43/preview
https://onlinecourses.nptel.ac.in/noc20_me91/preview

VI- Exit Option- 02-Generative Design

Course Code	Course Name	Teaching Scheme Weightage in Hr.					Evaluation Scheme Weightage in %				
		L	T	P	S	Cr	Theory			Laboratory	
							MSE	TA	ESE	ISE	ESE
tbd	**Generative Design**	3	1	0	1	4	30	20	50		

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

1. **Apply Generative Design Principles**: Understand and implement the fundamentals of generative design, including design space definition, objectives, and constraints, using both traditional and AI-driven methods.
2. **Develop Parametric and Algorithmic Models**: Create and manipulate parameter-driven and algorithmic models to enable automated design exploration and optimization workflows.
3. **Utilize Optimization and AI Tools**: Employ optimization techniques (topology, shape, evolutionary algorithms) and integrate AI/ML tools to guide and enhance mechanical design decisions.
4. **Solve Real-World Design Challenges**: Apply generative design tools and workflows to real-world engineering problems, incorporating data analysis, sustainability considerations, and advanced manufacturing technologies.

Syllabus:

Unit No.	Contents	Lecture
01	**Introduction to Generative Design** Contrast between traditional CAD/hand-design methods with AI-driven design exploration, design objectives vs. constraints, design space definition, overview of role of algorithms in autonomous generation of many feasible designs, real-world examples. Self study: Study and discuss real-world examples (e.g. a generatively designed chair or bracket) to illustrate faster, lighter, cost-effective solutions. Study interdisciplinary links, e.g. how data on loads/materials feed into design goals.	**6**

02	Parametric & Algorithmic Modelling Parametric design and its role in generative workflows, parameter-driven models - the basis of automated design exploration, constraint-based modelling in Fusion 360 (or similar), introduction to algorithmic (programmatic) design concepts, and parameters/data used to generate geometry. Self Study: Parametric variables in CAD, design tables. Basics of algorithmic design (e.g. using parameter lists or pseudocode to vary shapes). Comparison: parametric design vs. generative design. Setting up a CAD model for optimisation.	**6L**
03	Optimisation Techniques in Mechanical Design Content: Introduces optimisation fundamentals, objective functions, types of constraints, and the difference between shape/topology optimisation and generative design, classic optimisation algorithms (gradient-based vs. evolutionary) and multi-objective trade-offs, Topology optimisation (material distribution) - a precursor to generative design, evolutionary algorithms (genetic algorithms, particle swarm) and machine learning to guide design choices. Compared to shape optimisation (one solution), generative design produces many iterative models optimised for varied criteria. **Self Study:** Optimisation basics (objective, constraints), local vs. global optima. Topology optimisation (concept of removing material to achieve a light-weight design).	**6**
04	Unit 4: Generative Design Workflow and Tools Creating or importing a preliminary CAD model (the “design space”), applying loads and fixtures, setting up manufacturing constraints (like allowable manufacturing methods, symmetry), and specifying objectives (e.g. minimise weight), Use of cloud computing and AI simulation. Self Study: Study the process which explores all possible permutations of a solution in a software, quickly generating design alternatives. Learn Key skills include filtering and comparing outcomes (e.g. by stiffness vs. mass) and selecting feasible designs.	**6**
05	Data Science and AI Integration in Design Basic data analysis skills relevant to design: collecting performance data (from simulations or tests), plotting trends, and using simple statistics, machine learning models to predict design performance or assist optimization (e.g. regression to predict stress from geometry), the role of AI. Self-Study: Learn how machine learning allows the system to learn from each design iteration and continuously improves the design outcomes. Conceptual overview of ML in design (prediction vs. optimisation). Interdisciplinary ties: how manufacturing data or material databases feed generative processes.	**6**
06	Applications, Projects, and Future Trends Real-world applications of generative design in mechanical engineering (automotive parts, aerospace components, biomedical implants, consumer products), additive manufacturing (3D printing) and the concept of sustainable design (multi-materials, eco-criteria). Current trends (e.g. AI-driven digital twins, integration with IoT sensor data) and outlook. Self study: Additive manufacturing considerations (how design freedom allows complex shapes). Multi-objective optimisation	**6**

	(balancing weight, cost, aesthetics). Emerging trends: generative design in industry and research.	

Note: Content mentioned for self-study is integral part of the syllabus and it will be considered for evaluation of the course.

Suggested Learning Resources

1. Autodesk: Generative Design in Manufacturing
https://www.autodesk.com/learn/ondemand/course/generative-design-in-manufacturing
2. Autodesk: Fusion 360 Generative Design Overview
https://help.autodesk.com/view/fusion360/ENU/?guid=GD-OVERVIEW
3. Formlabs: Generative Design 101
https://formlabs.com/global/blog/generative-design
4. GUVI: Generative Design in Mechanical Engineering
https://www.guvi.in/blog/generative-design-in-mechanical-engineering/
5. Autodesk University: Fusion 360 Introduction to Generative Design
https://www.autodesk.com/autodesk-university/article/Fusion-360-Introduction-Generative-Design
6. All3DP Pro: Fusion 360 Generative Design – Hands-On Tutorial
https://all3dp.com/2/fusion-360-generative-design-tutorial/
7. ASME Digital Collection: Generative Design – Reframing the Role of the Designer
https://asmedigitalcollection.asme.org/mechanicaldesign/article/145/4/041411/1156493/Generative-Design-Reframing-the-Role-of-the
8. University of California, Santa Cruz: CMPM147 – Generative Design Course
https://courses.engineering.ucsc.edu/courses/cmpm147
9. Introduction to Generative Design for Manufacturing
https://www.autodesk.com/learn/ondemand/course/fusion360-generative-design-intro-expert
10. Generative Design Course
https://www.youtube.com/watch?v=PSSt8wswNJQ
https://www.youtube.com/watch?v=bDJQF0BbBBs
https://www.youtube.com/watch?v=oROzWsvK19o