DEPARTMENT OF MECHANICAL ENGINEERING

Scheme of Instruction
and
Syllabus of

M.E. (Mechanical Engineering)
TURBOMACHINERY
Full Time & CEEP

With effected from the Academic Year 2023-2024

UNIVERSITY COLLEGE OF ENGINEERING
(Autonomous)
Osmania University
Hyderabad–500 007

INSTITUTE

Vision

The Vision of the Institute is to generate and disseminate knowledge through a harmonious blending of Science, Engineering and Technology. To serve the society by developing a modern technology in students' heightened intellectual, cultural, ethical and humane sensitivities, fostering a scientific temper and promoting professional and technological expertise.

Mission

- To achieve excellence in Teaching and Research.
- To generate, disseminate and preserve knowledge.
- To enable empowerment through knowledge and information.
- Advancement of knowledge in Engineering, Science and Technology.
- Promote learning in free thinking and innovative environment.
- Cultivate skills, attitudes to promote knowledge creation.
- Rendering socially relevant technical services for the community.
- To impart new skills of technology development.
- To inculcate entrepreneurial talents and technology appreciation programmes.
- Technology transfer and incubation.

DEPARTMENT

Vision

To generate and disseminate knowledge in Mechanical Engineering and nurture professional, technical and scientific temper for serving the needs of the industry, research organizations and society.

Mission

- Create technically competent mechanical engineers to suit the changing needs of global industry and society.
- To cultivate skills, attitudes to promote knowledge creation and technology development.
- Interact with prominent educational institutions and R&D organizations for enhancing teaching, research and consultancy services.

ME (Mechanical Engineering)-Turbomachinery

Programme Educational Objectives (PEO):

The Post graduating students of the Turbomachinery program will be able to:

PEO1	To provide the requisite fundamentals on varied subjects of Turbomachinery, and the required skill sets in various laboratory experiments and engineering tools so that they recognize, analyze and solve related technical problems.
PEO2	To provide technical knowledge in turbomachines to analyze and solve innovatively not only thermal related technical problems, but also be able to model analyze, design the systems for varied through the modern engineering tools, be they experimental and analytical tackling engineering problems independently but also engage in generation of new ideas in Industry or Government.
PEO3	To provide various methods to communicate (written & oral) with fellow engineers, employers and continuous learning techniques for professional challenges and the skills needed to excel their social duties and responsibilities in teamwork, collegiality and ethics.
PEO4	To motivate them to learn on their own, think critically and creatively in order to evaluate new ideas, and provide innovative solutions, with requisite practical and managerial experience, will be able to start activities and transform into entrepreneurs.

Programme Outcomes (PO):

PO1:	An ability to independently carry out research /investigation and development work to solve practical problems
PO2:	Ability to write and present a substantial technical report/document
PO3:	Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program
PO4:	Able to use approximate numericaltechniques/computational techniques and interpret the results.
PO5:	Able to take up an industrial problem and function as a member of multidisciplinary team.

With effect from the Academic year 2023-2024

AICTE-Model Scheme
Scheme of Instructions & Examination
M.E. (Mechanical Engineering) 4 Semesters (Full Time)

S.No.	Subject	Scheme of Studies per Week		Max. Marks		Credits
		L	P	CIE	SEE	
Semester-I						
1.	Program Core I	3	-	40	60	3
2.	Program Core II	3	-	40	60	3
3.	Program Core III	3	-	40	60	3
4.	Program Elective I	3	-	40	60	3
5.	Program Elective II	3	-	40	60	3
6.	Program Elective III	3	-	40	60	3
7.	Laboratory I	0	2	50	--	1
8.	Seminar	0	2	50	--	1
	Total	**18**	**4**	**340**	**360**	**20**
Semester-II						
1.	Program Core IV	3	-	40	60	3
2.	Program Core V	3	-	40	60	3
3.	Program Core VI	3	-	40	60	3
4.	Program Elective IV	3	-	40	60	3
5.	Program Elective V	3	-	40	60	3
6.	Open Elective	3	-	40	60	3
7.	Laboratory II	-	2	50	--	1
8.	Laboratory III	-	2	50	--	1
9.	*Mini Project	-	4	50	--	2
	Total	**18**	**8**	**390**	**360**	**22**
Semester-III						
1.	Audit Course I	2	-	40	60	0
2.	Audit Course II	2	-	40	60	0
3.	Dissertation Phase I	-	20	100	--	10
	Total	**4**	**20**	**180**	**120**	**10**
Semester-IV						
1.	Dissertation Phase II	0	32	100	100	16
	Grand Total	**40**	**64**	**1010**	**940**	**68**

Total Credits: 20 + 22 + 10 + 16 = 68

Note:

i. Dissertation-II has two parts, CIE - I and CIE – II, at the end of 8th week and 16th week respectively for evaluation of 50 marks each.

ii. Audit Courses will be offered in ONLINE mode and SEE will be conducted in Computer Based Test Mode.

iii. Research Methodology in Mechanical Engineering will be offered as an Audit Course for all PG Programs.

iv. Engineering Research Methodology Workshop will be conducted for one week for Ph.D. scholars.

If the student is selected for Industry Internship, then he/she has to complete the required courses of Program elective V and Open Elective through ***SWAYAM-NPTEL MOOCS*** *Courses for getting the required credits. However, the students are required to consult Head & CBoS (Autonomous) for due approval, before he/ she registers for the course in SWAYAM-NPTEL portal.*

With effect from the academic year 2023-2024

M.E. Mechanical Engineering.(Turbomachinery)

Type of course	Course Code	Course Name	Contact hours per week		Scheme of Examination		Credits
			L	P	CIE	SEE	
SEMESTER-I							
Core-I	ME201	Principles of Turbomachinery	3		40	60	3
Core-II	ME202	Fluid Flow and Gas Dynamics	3		40	60	3
Core-III	ME203	Design of Gas Turbines	3		40	60	3
Program Elective-I	ME211	Experimental Techniques in Turbomachines	3		40	60	3
	ME212	Design of Thermal Systems					
	ME213	Cryogenic Engineering					
	ME325	Rotor Dynamics					
Program Elective-II	ME214	Power Plant Steam Generators	3		40	60	3
	ME215	Alternate Fuels and Emissions					
	ME304	Fluid Power Systems					
	ME315	Vibration Analysis and Condition Monitoring					
Program Elective-III	ME216	Fuels and Combustion	3		40	60	3
	ME217	Energy Systems and Management					
	ME 124	Optimization Techniques					
	ME311	Finite Element Techniques					
Lab-I	ME251	Turbomachinery laboratory		2	50	-	1
Seminar	ME261	Seminar		2	50	-	1
TOTAL			**18**	**4**	**340**	**360**	**20**
SEMESTER-II							
Core-IV	ME204	Heat Transfer and Heat Exchangers in Power Plants	3		40	60	3
Core – V	ME205	Design of Steam Turbines	3		40	60	3
Core -VI	ME206	Cascade Aerodynamics	3		40	60	3
Program Elective-IV	ME218	Computational Fluid Dynamics	3		40	60	3
	ME219	Combustion and Emission Control					
	ME220	Turbulent Flows					
	ME221	Flow Induced Vibrations					
Program Elective-V	ME222	Advanced Energy Systems	3		40	60	3
	ME223	Two Phase Flow and Heat Transfer					
	ME224	Design of Pumps and Compressors					
	ME225	Hydraulic Machinery					
Open Elective	OE941BM	Medical Assistive Devices	3		40	60	3
	OE942BM	Medical Imaging Techniques					
	OE941CE	Green Building Technology					
	OE942CE	Cost Management of Engineering Projects					
	OE941CS	Business Analytics					
	OE941EC	Elements of Embedded Systems					
	OE941EE	Waste to Energy					
	OE942EE	Power Plant Control and Instrumentation					
	OE941ME	Operations Research					
	OE942ME	Composite Materials					
	OE943ME	Industrial Safety					

	OE941LA	Intellectual Property Rights					
Lab-II	ME252	Computational Fluid Dynamics Laboratory		2	50	-	1
Lab-III	ME253	Computational Lab for TM		2	50	-	1
MC	MC070	Mini Project		4	50		2
TOTAL			**18**	**8**	**390**	**360**	**22**

SEMESTER-III							
Audit Course-I (Online)	AC030ME	Research Methodology in Mechanical Engineering	2		40	60	0
Audit course-II (Online)	AC 031	English for Research Paper Writing	2		40	60	0
	AC 032	Disaster Mitigation & Management					
	AC 033	Sanskrit for Technical Knowledge					
	AC 034	Value Education					
	AC 035	Stress Management by Yoga					
	AC 036	Personality Development Through LifeEnlightenment Skills					
	AC 037	Constitution of India					
	AC 038	Pedagogy Studies					
	AC 039	E-Waste Management					
Dissertation-I	ME281	Dissertation Phase-I		20	100		10
TOTAL			**4**	**20**	**180**	**120**	**10**
SEMESTER-IV							
Dissertation-II	ME282	Dissertation Phase-II		32	100	100	16
GRANDTOTAL			**40**	**64**	**1010**	**940**	**68**

CIE : Continuous Internal Evaluation SEE : Semester End Examination

SEMESTER-I

ME201	**PRINCIPLES OF TURBOMACHINERY**					
(PROGRAME CORE-I)						
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60Marks	**CIE**		40Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	Provide overview of different types of turbomachinery used for energy transformation
2	Derive governing equation designs of turbomachines
3	Draw velocity triangles and calculate specific work and power for characterizing turbomachinery stages
4	Determine the performance of turbomachinery stages operating at design and off design conditions

Course Outcomes:	
On completion of this course, the student will be able to:	
CO-1	Classify turbomachines and formulate governing equations of fluid flows and calculate efficiency of compressor and turbine.
CO-2	Derive equation for specific work of a turbomachine and factors effecting the deviation of specific work and cavitation.
CO-3	Examine principles of axial flow compressors, propellers and calculate performance parameters.
CO-4	Explain working principles of centrifugal compressor and able to draw velocity diagrams, and calculate performance parameters.
CO-5	Analyse steam turbines and able to draw velocity diagrams and calculate efficiency of steam turbines.

Program Articulation Matrix

Course outcome	**Program Outcome**				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	3	2	-	-	-
CO-2	3	2	-	-	-
CO-3	3	3	1	-	-
CO-4	3	3	1	-	-
CO-5	3	3	1	-	-

Unit– I
Introduction to Turbomachines. Classification of Turbomachines. Second Law of Thermo dynamics - turbine/compressor work, Nozzle/diffuser work. Fluid equations - continuity, Euler's, Bernoulli's equation and its applications. Expansion and compression processes, Reheat Factor, Preheat Factor.

Unit– II
Euler's Equation of Energy Transfer, vane congruent flow, influence of relative circulation, thickness of vanes, number of vanes on velocity triangles, slip factor, Stodola, Stanitz and Balje's slip factor. Suction pressure and net positive suction head. Phenomena of cavitations in pumps. Concept of specific speed, Shape number. Axial, Radial and Mixed Flow Machines. Similarity laws.
Unit– III
Flow through Axial flow fans. Principles of Axial fan and propeller. Application of fans for air circulation and ventilation. Stage pressure rise and work done. Slip stream and Blade Element theory for propellers. Performance and characteristics of Axial fans.
Unit– IV
Flow through Centrifugal compressors. Stage velocity triangles, specific work. Forward, radial and backward swept vanes. Enthalpy entropy diagram, degree of reaction, slip factor, efficiency. Vane less and vaned diffuser systems, volute as spiral casing. Surge and stall in compressors
Unit–V
Steam turbine stages, stage velocity triangles, work, efficiency, blade loading, flow coefficient. Single stage impulse and reaction turbines, degree of reaction, 50% reaction turbine stage, Radial equilibrium and Actuator disc approach for design of turbine blades. Partial admission problems in turbines. Losses in turbo machines.
Topics to be taught by Industry Subject Expert :
Industrial applications of Turbomachines and Case studies

Suggested Reading:

1	S.M. Yahya, Turbines, Compressors and Fans, Fourth Edition, Tata Mcgraw Hill, 2011
2	Gopalakrishnan G, Prithvi Raj D, A treatise on Turbomachines, Scitec Publications, Chennai, 2002.
3	D.G.Sheppard, Principles of Turbomachinery, Macmillan
4	R.K.Turton, Principles of Turbomachinery, Second Edition, Chapman & Hall
5	Balje, Turbomachinery–Theory, Design and Practice. John Wiley & Sons

ME202	**FLUID FLOW AND GAS DYNAMICS**					
(PROGRAMECORE–II)						
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60Marks	**CIE**		40Marks	

Course Objectives:	
On completion of this course, the student will be able to:	
1	Analyze compressible flow through constant and variable area duct
2	Apply Fluid mechanics principles to propulsive system
3	Understand the basic characteristics of compressible flows, including wave propagation, speed of sound and the Mach number.
4	Distinguish normal shock, oblique shock and Prandtl Meyer flows.

Course Outcomes:	
On completion of this course, the student will be able to do:	
CO-1	Develop mathematical models for flow phenomena and understand concepts of fluid motion.
CO-2	Analyse fundamental conservation equations for fluid flow.
CO-3	Understand flow phenomena over an airfoil and boundary layer formation.
CO-4	Apply mathematical relations for compressible fluid flow phenomena.
CO-5	Formulate and apply mathematical relations for Supersonic fluid flow phenomena through variable flow passages.

Program Articulation Matrix

Course outcome	**Program Outcome**				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	3	3	-	3	-
CO-2	3	3	-	2	-
CO-3	3	3	-	2	1
CO-4	3	3	-	3	-
CO-5	3	3	3	3	-

Unit-I
Fluid flow: Classification of fluids. Lagrangian and Eularian Methods of Study of fluid flow. Velocity and acceleration vectors. Circulation and Vorticity. Stream lines. Stream tube. Path lines. Streak lines and Time lines. Stream function and Potential function.
Unit-II
Basic laws of fluid flow – Continuity. Euler's and Bernoulli's equations. Incompressible and Compressible flows. Potential and viscous flows. Navier – Stoke's equation and applications.

Unit-III
Flow over an airfoil – Lift and Drag coefficients. Boundary layer theory – laminar and turbulent boundary layers. Hydrodynamic and thermal boundary layer equations. Flow separation in boundary layers.
Unit-IV
Gas dynamics: Energy equation for flow and non flow processes. Application of Steady flow energy equation for turbines, turbo-compressors, nozzles and diffusers. Adiabatic energy equation. Acoustic velocity, Mach Number. Stagnation properties. Relationships between static and stagnation properties. Various regimes of flow – Steady flow ellipse.
Unit-V
Isentropic flow through variable area passages. Design of supersonic and subsonic nozzles and diffusers. Supersonic flows. Expansion and Shock waves. Normal and Oblique Shock waves. Prandtl-Meyer and Rankine-Hugoniot Relations. Simple problems on normal and oblique shock waves.
Topics to be taught by Industry Subject Expert :
Industrial applications of fluid flow and gas dynamics in turbomachines and Case studies

SuggestedReading:

1	C P Kothandaraman, R Rudramoorthy, Basic Fluid Mechanics, New Age Intl. Publishers,1999
2	S.M. Yahya, Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion, Third Edition, New Age Intl. Publishers
3	Zoeb Hussain, Gas Dynamics Though Problems, John Wiley and Sons
4	P. Balachandran, Fundamentals of compressible fluid dynamics, PHI Learning Pvt. Ltd, 2006
5	Ethirajan Rathakrishnan, Gas Dynamics, PHI Learning,2017

ME203	**DESIGN OF GAS TURBINES**					
(PROGRAMECORE-III)						
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60Marks	**CIE**		40Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	Understand the thermodynamics of each component of a turbine engine which include inlets, fans, compressors, burners, turbines, afterburners and nozzles
2	Know the design variables for each components
3	Understand the connected system performance of all components in the engine and performance trends
4	Understand the basis for off-design performance

Course Outcomes:	
On completion of this course, the student will be able to do:	
CO-1	Understand various gas turbine cycles.
CO-2	Analyse laws pertaining to gas turbines and compressors
CO-3	Identify, formulate and solve problems related to gas turbines
CO-4	Estimate the performance of turbines
CO-5	Design turbine components and combustion chambers

Program Articulation Matrix

Course outcomes	**Program outcomes**				
	PO1	**PO2**	**PO3**	**PO4**	**PO5**
CO1	3	2	1	2	1
CO2	3	3	2	2	2
CO3	3	3	2	2	2
CO4	2	3	2	3	2
CO5	3	3	3	2	2

Unit-I

Thermodynamic analysis of Gas turbine power cycles – Joule/Brayton. Open and Closed Cycles. Methods of improving cycle efficiency – Inter cooling. Reheating and Regeneration.

Unit-II

Applications of Turbo Compressors (Centrifugal and axial flow) in Gas turbine power plant. Euler equation of energy transfer in a turbomachine. Design of two stage centrifugal compressor with vane less and vaned diffusers. Design of multi stage axial flow compressors.

Unit-III
Types of combustion chambers. Combustion chamber design for modern gas turbines. Can type, annular and tube type of combustors.
Unit-IV
Analysis and design of 2-D and 3-D flow for axial flow turbines. Matching of compressor and turbine for varying load operation. Gas turbine for super charging and cryogenic applications. Small gas turbines for space applications.
Unit-V
Design and construction of Gas turbine rotors and blades. Blade materials. Blade attachment techniques. Cooling methods of turbine blades. Simple analysis of turbine blade vibrations and balancing of rotors. Case studies
Topics to be taught by Industry Subject Expert :
Case studies related to performance of Turbines, problems encountered in turbines and rectification measures taken for solving the problems.

Suggested Reading:

1	D.G.Wilson, The Design of High efficiency Turbomachinery and Gas Turbines, The MIT Press, Cambridge, U.K. 2014
2	M.P.Boyce, Gas Turbine Engineering hand book, Gulf Publishing Co., New York. 2002
3	O.E. Balje, Turbo machines–A guide to Selection and Theory, John Wiley & Sons, New York.
4	J.S. Rao, Rotor Dynamics, Wiley Eastern Publication, New Delhi,2005
5	Meinhard T. Schobeiri, Gas Turbine Design, Components and System Design Integration, Springer, 1st Edition, 2017

ME211	**EXPERIMENTAL TECHNIQUES IN TURBOMACHINES**					
(PROGRAMEECTIVE– I)						
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60Marks	**CIE**		40Marks	

Course Objectives:	
On completion of this course, the student will be able to:	
1	To develop ability to test and diagnose a new turbomachinery stage or system
2	Introduces a variety of instruments and transducers available for performance, flow, and structural measurement in turbomachines.
3	Understand the importance of high-quality test data, and the procedures necessary to obtain and process that data
4	To design test programs to achieve practical measurements and data reduction.
5	Understand fluid dynamics and structural evaluations of turbomachines.

Course Outcomes:	
On completion of this course, the student will be able to:	
CO-1	Familiarize to experimental design protocols and plan for design
CO-2	Understand the calibration methods and also data acquisition systems and usage.
CO-3	Demonstrate flow visualization techniques and flow measurement devices.
CO-4	Design and conduct experiments, as well as to organize, analyze and interpret data to produce meaningful conclusions and recommendations
CO-5	Identify, formulate and solve complex turbomachinery problems

Course outcomes	**Program outcomes**				
	PO1	**PO2**	**PO3**	**PO4**	**PO5**
CO1	3	2	1	1	1
CO2	3	1	2	3	1
CO3	3	1	2	2	1
CO4	3	3	3	3	1
CO5	3	3	2	3	1

Unit– I
Experiment planning, experiment design factors. Classification of measurement techniques. Conventional techniques for measurement of Flow, Pressure, Temperature and Velocity in turbomachinery passages.
Unit– II
Temperature measuring devices – Thermo electric thermometry and pyrometry. Instantaneous pressure measurement using pressure transducers, Pitot tube, probes. Boundary layer measurement. Calibration of probe.

Unit– III
Wind tunnels: Schematic layout of wind tunnel with test section, subsonic, transonic and supersonic wind tunnels. Measurement of turbulence using a Hot wire anemometer and Laser Doppler anemometer.
Unit– IV
Calibration methods and signal processing techniques. General data acquisition system Data transmission, A/D and D/A conversion, Recorders with digital display.Data collection and storage.
Unit– V
Flow measurement instruments, Flow Visualization techniques – conventional and optical methods. Radar Doppler and Laser velocimeter. Brief description of error and uncertainty analysis.
Topics to be taught by Industry Subject Expert :
Applications and Case studies related to Experimental Techniques

Suggested Reading:

1	David Japikse, Advanced Experimental Techniques In Turbomachinery, Atlantic Books, 1997
2	J. P. Holman, Experimental Methods for Engineers, 8thEdition,McGraw-Hill, 2012
3	Russell Mikel, Wind Tunnels: Models, Aerodynamics and Applications, Clanrye International, 2015
4	Thomas G. Beckwith, Roy D. Marangoni, John H. Lienhard V, Mechanical Measurements, 6th Edition, Pearson Education, 2020
5	A.K.Tayal, Instrumentation, Mechanical Measurements and Control: 2nd Edition, Galgotia Publications Pvt Ltd 2008

ME212	**DESIGN OF THERMAL SYSTEMS**					
	(PROGRAMELECTIVE– I)					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60Marks	**CIE**		40Marks	

Course Objectives:	
On completion of this course, the student will be able to:	
1	Understand design aspects of heat exchangers and ancillary equipment
2	Apply thermo-economic optimization techniques and provide with experience in using computer based methods to solve problems
3	Revise the system design to optimize its performance
4	Provide an introduction to computer-aided design of thermal systems, including performance factors, such that cost-optimized configurations can be found.
5	Emphases on equipment selection, system analysis and synthesis.

Course Outcomes:	
On completion of this course, the student will be able to:	
CO-1	Design and conduct experiments, as well as to organize, analyze and interpret data to produce meaningful conclusions and recommendations
CO-2	Identify thermal systems, components to meet desired need within realistic constraints such as manufacturability, sustainability and safety
CO-3	Formulate and solve complex Thermal systems
CO-4	Apply modern engineering tools necessary for design of thermal systems
CO-5	Evaluate optimization techniques for improving the performance of thermal systems

Program Articulation Matrix

Course outcomes	**Program outcomes**				
	PO1	**PO2**	**PO3**	**PO4**	**PO5**
CO1	3	3	2	2	1
CO2	3	3	2	2	1
CO3	3	3	2	2	1
CO4	3	2	2	3	1
CO5	3	3	2	3	1

Unit– I

Engineering Design: Introduction – Need – Criteria of Success – Probability of success – Market analysis– Feasibility – R&D – Iteration – Optimization of operation – Technical design. Designing a Workable System: Workable and optimum system – Design of a Food Freezing Plant – Preliminaries to the study of Optimization. Economics: Interest – lump sum, Compounded annually – lump sum Compounded more often than annually – Compound – amount factor (f/p) and present – worth factor (p/f) Future worth of a uniform series of amounts – Present worth of a uniform series of amounts – Gradient present work factor – Bonds – Shift in time of a series – Evaluating potential investments. Taxes – Depreciation – Influence of Income Tax.

Unit– II
Modelling Thermal Equipment: Selecting Vs. Simulating a heat exchanger – Binary solutions – Temperature– Concentration – Pressure Characteristics – Developing T Vs. – x diagram – condensation of a Binary mixture Single – Stage distillation – Rectification – Pressure drop and pumping power – Turbo machinery. System Simulation: Classes of simulation – Sequential and simultaneous calculations – Simulation of a gas Turbine system.
Unit– III
Optimization: Levels of Optimization – Optimization procedures – Lagrange Multipliers – Search Methods Dynamic Programming – Geometric Programming, Linear Programming.
Unit– IV
Thermodynamic Properties Modeling: The form of the equation – P-V-T equations – P-T relation for saturation conditions. P/f density of liquid. The clayperon equation – Maxwells relations.
Unit– V
Dynamic Behavior of Thermal Systems: Calculus Methods of Optimization – Calculus of variations and Dynamic Programming – Probabilistic Approaches to design. Application of Design of Thermal Systems in design and development of turbomachines. Case studies

Suggested Reading:

1	Stoecker, W.F., Design of Thermal Systems, McGraw-Hill Book Company, 1987.
2	C.Balaji, Essentials of Thermal System Design and Optimization, Ane Books Pvt. Ltd,2011
3	Steven G. Penoncello, Thermal Energy Systems: Design and Analysis ,CRC Press, 2015
4	Yogesh Jaluria, Design and Optimization of Thermal Systems, McGraw-Hill Education, 1998

ME213	**CRYOGENIC ENGINEERING**					
(PROGRAMELECTIVE– I)						
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60Marks	**CIE**		40Marks	

Course Outcomes:	
On completion of this course, the student will be able to:	
CO-1	To gain knowledge and to understand the scope and history of cryogenics. To understand the properties of materials at low temperature applying fundamental knowledge.
CO-2	To apply the knowledge of low temperature production methods to understand and analyse different liquefaction systems. To gain knowledge about the critical components involved in liquefaction.
CO-3	To apply the knowledge of ideal refrigeration techniques, to understand and analyse common cryogenic refrigeration systems. To understand some of the novel cryogenic refrigeration methods.
CO-4	To gain knowledge and to understand various cryogenic fluid storage and transport systems and to evaluate their performance applying fundamental concepts
CO-5	To gain knowledge about different cryogenic instrumentation and to understand cryo pumping.

Course outcomes	**Program outcomes**				
	PO1	**PO2**	**PO3**	**PO4**	**PO5**
CO1	2	3	2	2	1
CO2	2	2	3	2	1
CO3	3	3	2	2	2
CO4	2	2	2	3	1
CO5	2	3	2	3	2

Unit– I

Vapour Compression Refrigeration Systems: Analysis of vapor compression refrigeration cycle, Second law of Thermodynamics, Carnot refrigerator, Vapor Compression Refrigeration Cycle, components, Properties of Refrigerants.

Unit– II

Thermodynamic Property Relations: Helmholtz and Gibbs Functions, two Mathematical Conditions for Exact Differentials, Maxwell Relations, Clapeyron Equation, Relations for Changes in Enthalpy, Internal Energy and Entropy, Specific Heat Relations, Generalized Relations/Charts for Residual Enthalpy and Entropy, Gibbs Function at zero Pressure: A Mathematical Anomaly, Fugacity, Fugacity Coefficient and Residual Gibbs Function, The Joule, Thomson Coefficient and Inversion Curve, Thermodynamic similarity.

Unit– III
Non-reacting Mixtures of Gases and Liquids: Measures of Composition in Multi Component Systems. **Gas Mixtures:** Mixtures of ideal Gases, Gas-Vapor Mixtures, Application of First Law to Psychometric Processes, Real Gas Mixtures. **Liquid Mixtures/Solutions:** Ideal Solutions, Real Solutions. **Thermodynamic Relations for Real Mixtures:** Partial Properties, Relation for Fugacity and Fugacity Coefficient in Real Gas Mixtures, Relations for Activity and Activity Coefficient in Real Liquid Mixtures/Solutions.
Unit– IV
Phase Equilibrium: Vapour Liquid Equilibrium of Mixtures: Phase Diagrams for Binary Mixtures, Vapor, Liquid Equilibrium in Ideal Solutions, Criteria for Equilibrium, Criterion foe phase Equilibrium, Calculation of Standard State Fugacity of Pure Component, Vapor Liquid Equilibrium at Low to Moderate Pressures, Determination of Constants of Activity Coefficient Equations, Enthalpy Calculations.
Unit– V
Chemical Reactions and Combustion: Thermo chemistry, Measures of Composition in Chemical Reactions, Application of First Law of Thermodynamics to chemical Reactions, the Combustion Process-Standard Heat/Enthalpy of Combustion, Reactions at actual Temperatures, adiabatic Flame Temperature, Entropy Change of Reacting Systems, Application of second Law of Thermodynamics to chemical Reactions, chemical equilibrium-Advancement of Chemical Reactions, Equilibrium Criterion in Chemical Reactions, equilibrium Constant and Law of Mass Action, Equilibrium Constant for Gas Phase Reactions in the standard state.
Topics to be taught by Industry Subject Expert :
Application of cryogenic engineering and production of cryogenic fluids.

Suggested Reading:

1	P.K.Nag, Basic and Applied Thermodynamics, TMH, 2019.
2	J.P Holman, Thermodynamics, McGraw Hill, 2017.
3	CP Arora, Thermodynamics ,McGraw Hill education (India Pvt limited), 2016.
4	C.P. Arora, Refrigeration & Air, Conditioning, TMH, 2017
5	R.F Barron ,Cryogenic Systems , Oxford University Press
6	Stoecker W.F. Jones, Refrigeration& Air Conditioning, J.W., McGraw Hill, 2014.
7	Manohar Prasad, Refrigeration &Air Conditioning, New Age, 2018 .
8	Domkunduwar, and Arora, Refrigeration & Air Conditioning Dhanpatrai & Sons, 2015.
9	Randal F.Barron, Cryogenic systems, McGraw Hill, 1986
10	Klaus D.Timmerhaus and Thomas M.Flynn, Cryogenic Process Engineering, Plenum Press, New York

ME325	**ROTOR DYNAMICS**					
(PROGRAMELECTIVE– I)						
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60Marks	**CIE**		40Marks	

Course Objectives:	
On completion of this course, the student will be able to:	
1	Understand the rotor dynamics phenomena with the help of simple rotor models and subsequently the modern analysis methods for real life rotor systems.
2	develop modeling and analysis of rotor-bearing dynamics
3	Identify and condition monitoring of rotor-bearing systems.
4	Analyze rotors for the transverse and torsional vibrations.
5	Understand undamped and damped natural frequencies and Forced response for steady and unsteady excitation

Course Outcomes:	
On completion of this course, the student will be able to:	
CO-1	Understand fluid film lubrication, boundary conditions, stiffness and damping coefficients.
CO-2	Identify different types of rotors in rotor bearing system, fluid film lubrication and stability and instability of rotors.
CO-3	Analyse the principles of rotor dynamics for predicting the stability of the rotor.
CO-4	Design bearings, shafts and rotor stages to predict instability
CO-5	Analyse critical speed in rotor dynamics and different analytical methods for determining the same.

Program Articulation Matrix

Course outcome	**Program outcome**				
	PO1	**PO2**	**PO3**	**PO4**	**PO5**
CO1	3	3	3	1	1
CO2	2	3	2	3	1
CO3	2	3	2	2	1
CO4	2	3	2	2	1
CO 5	2	2	2	2	1

Unit– I
Single degree of freedom system – Free vibrations. Damped vibrations and forced vibrations, Two degree of freedom systems – Undamped vibration, absorbers, Forced Damped vibrations, Vibration isolation.
Unit– II
Close coupled systems – Eigen value problem. Orthogonality of mode shapes. Modal analysis Critical speeds.

Unit– III
Vibrations of multi rotor systems – Matrix method, Influence coefficient methods, Transfer matrix analysis and Holzers method.
Unit– IV
Torsional vibrations in rotating machinery – Equivalent discrete system, transient response, branched system.
Unit– V
Out-of-rotors in rigid supports, simply supported rotor with overhangs. Gyroscopic effects. Rotor mounted on fluid film bearings – Transfer matrix analysis of turbine rotor by distributed elements, Dual rotor system analysis. Balancing of rotors. Application of rotor dynamics in improvement of performance of turbomachines. Case studies

Suggested Reading:

1	J.S. Rao, Rotor dynamics. New Age International; Third edition, 2018
2	J.S. Rao, K. Gupta, Mechanical Vibrations. John Wiley & Sons Inc
3	Kicinski Jan, Rotor Dynamics: Institute Of Fluid- Flow Machinery ,Techniz Books International, 2010
4	Giancarlo Genta, Dynamics of Rotating Systems, Springer; 2005
5	Michael I. Friswell, John E. T. Penny, Seamus D. Garvey, Arthur W. Lees ,Dynamics of Rotating Machines, Cambridge University Press; Illustrated edition, 2010

ME214	**POWER PLANT STEAM GENERATORS**					
	(PROGRAMELECTIVE– II)					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60Marks	**CIE**		40Marks	

Course Objectives:	
On completion of this course, the student will be able to:	
1	Understand and know the requirements for a Thermal Power Plant, from sources to consumption
2	Study and learn the processes and cycles followed in Thermal Power Plants and components used in the power plants**.**
3	Gain the knowledge on steam power plants, steam generators analyses on fuel and fluidized bed combustion, ash handling systems.
4	Learn the practices followed in Thermal Power Plant, to better environmental conditions and the safety measures.
5	To estimate efficiencies in a steam power plant and calculate economics of power plants.

Course Outcomes:	
On completion of this course, the student will be able to:	
CO-1	Understand the various sources of energy.
CO-2	Identify Equipment, Plant layout, principle of working of various plants.
CO-3	Understand the various combustion systems.
CO-4	Understand the working principles of various boilers
CO-5	Design furnaces and burners

Program Articulation Matrix

Course outcomes	**Program outcomes**				
	PO1	**PO2**	**PO3**	**PO4**	**PO5**
CO1	3	2	2	2	1
CO2	3	3	2	2	1
CO3	2	2	2	2	1
CO4	2	3	2	2	1
CO5	2	2	2	3	1

Unit– I
Introduction-steam generation, Nucleate & Film Boiling, circulation ratio, Natural, Assisted and Forced Circulation Boilers. Super Critical Boilers.
Unit– II
Requirements in modern boilers, Types of steam generators and their construction and application, Fuels and Fuel Handling systems, for steam generators.

Unit– III
Air-handling systems, Combustion in combustion systems with different types of fuels, combustion calculations, Once-thro‟ boilers, Fluidised bed combustion boilers, Cyclone furnace boilers.
Unit– IV
Furnace sizing, Burner selection and design combined cycle power plant steam generators, Emissions from steam generators and its control.
Unit– V
Boiler maintenance, safety regulation and inspection, Ash handling Case study of typical modern boiler systems. Case studies.

Suggested Reading:

1	W.J. Kearton, Steam Turbine Theory and Practice, CBS Publishers, 2004
2	Ian Gordon Cumming Dryden, The Efficient Use of Energy, Butterworth-Heinemann Ltd; 2nd Revised edition
3	James Fay, Dan Golomb, Energy and The Environment: Scientific and Technological Principles, Oxford University Press; 2nd edition, 2011
4	Allan Bennett Gill, Power Plant Performance, Butterworth-Heinemann Ltd
5	R.K.Hegde, Power Plant Engineering, Pearson, 2015

ME215	**ALTERNATE FUELS AND EMISSIONS**					
(PROGRAMELECTIVE– II)						
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60Marks	**CIE**		40Marks	

Course Objectives:	
On completion of this course, the student will be able to:	
1	Identify the working mechanism of internal combustion engines
2	Explore the possibility of replacing petrol and diesel with alternate fuels
3	Compare the basic parameters such as acceleration and mileage with both fuels
4	Investigate the pollution generated by alternate fuels and control
5	Finally, the source of alternate fuels (trees) and their role in emission control.

Course Outcomes:	
On completion of this course, the student will be able to:	
CO-1	Understand the need of alternate fuels
CO-2	Evaluate the performance of the engine with alternate fuels and blends with petroleum derived fuels.
CO-3	Examine the viable production and storage methods of alternate fuels.
CO-4	Measure the pollutant emissions as per standards and describe emission control methods.
CO-5	Evaluate the production methods in other countries and estimating time in growth

Program Articulation Matrix

Course outcomes	**Program outcomes**				
	PO1	**PO2**	**PO3**	**PO4**	**PO5**
CO1	3	2	2	2	1
CO2	3	3	2	2	2
CO3	2	2	2	2	1
CO4	2	3	2	2	2
CO5	2	2	2	3	1

Unit– I

Introduction: Present energy scenario (worldwide and India)- Statistics of petroleum fuels- of liquid and gaseous fuels in Automobiles-Problems with highly exploited petroleum derived fuels-Desirable properties of a good alternate fuel – Availability and properties of alternate fuels, ASTM standards.

Alcohols: General Use of Alcohols – Thermo-combustion properties as Engine fuel – Gasoline and alcohol blends – Production methods of widely used alcohols-Performance in SI and CI Engines – Methanol and ethanol and Gasoline/diesel blends – Combustion Characteristics in engine – emission characteristics-Modification required to operate with alcohols and its blends with petrol and diesel-brief details of flexi fuel engines(FFE)-use of higher alcohols.

Unit– II
Natural Gas, LPG: Use of natural gas as CNG and LNG-Availability of CNG and LNG-, properties, modification required to use in engines – performance and emission characteristics of CNG using LPG in SI & CI engines.-Production and storage of CNG/LNG. **Bio-gas:** Production methods of bio-gas, properties of bio-gas as a fuel, performance and emission characteristics of engine with bio-gas and its blends with petrol/diesel-brief information on compressed gio-gas and its storage.
Unit– III
Vegetable oils: Characteristics of vegetable oils as alternate fuel- edible and non-edible vegetable oils-conversion of vegetable oils into diesel like fuel(biodiesel) -esterification, blending and micro-emulsions-Performance and emission characteristics of engines with biodiesel and blends-B20. **Hydrogen :**Suitable characteristics of hydrogen fuel- hydrogen production methods- storage of hydrogen-use of hydrogen as fuel in engines -Hydrogen in fuel cells.
Unit– IV
Engine Emissions: Harmful effects of engine-out emissions-Mechanism of formation of pollutant emissions such as carbon monoxide, unburned hydrocarbons, oxides of hydrogen and aldehydes.
Unit– V
Emission measurement and control methods: Measurement of pollutants using flame ionization detection, NDIR, chemilumines centanalyzer and particulate matter(soot/smoke)-Emission norms-EURO and Bharat stage Engine emission control methods-in cylinder and after treatment methods.
Topics to be taught by Industry Subject Expert :
Case studies, Application of alternative fuels in turbomachines. Exposure to kickbacks in production of transport vehicles to suit Indian conditions with alternate fuels

Suggested Reading:

1	M.K. Gajendra Babu , K.A. Subramanian, Alternative Transportation Fuels: Utilisation in Combustion Engines, CRC Press ,2013
2	Akhilendra Pratap Singh, Yogesh C. Sharma, Alternative Fuels and Their Utilization Strategies in Internal Combustion Engines, Springer 2020.
3	Norbe Pundir B.P, Engine Emissions: Pollutant formation and advances in control Technology, Narosa Publishing House, 2013.
4	Ramadhas, A S, Alternative Fuels for Transportation, CRC Press 2012.

ME304	**FLUID POWER SYSTEMS**					
	(PROGRAMELECTIVE– II)					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60Marks	**CIE**		40Marks	

Course Objectives:	
On completion of this course, the student will be able to:	
1	The course will develop the students' knowledge and understanding of hydraulic and pneumatic devices and systems.
2	The students should be able to understand the principles of operation and the design details of hydraulic pumps, motors, valves, actuators, and systems.
3	The student should be able to analyze both the steady-state and the dynamic performance of individual hydraulic components and systems.
4	The student should also be able to relate the theory with the practical applications of these principles

Course Outcomes:	
On completion of this course, the student will be able to:	
CO-1	Differentiate between Hydraulic and Pneumatic systems and Identify various hydraulic and pneumatic elements with their symbols
CO-2	Classify various hydraulic, pneumatic fluids with their properties & applications and Illustrate the working principles of various positive displacement pumps and motors.
CO-3	Generate and solve mathematical models for various hydraulic & pneumatic components like valves, pumps and motors
CO-4	Integrate all hydraulic & pneumatic components and solve the corresponding mathematical models for generating various fluidic circuits
CO-5	Apply the concept of fluidics in developing various fluidic circuits

Program Articulation Matrix

Course outcome	**Program outcome**				
	PO1	**PO2**	**PO3**	**PO4**	**PO5**
CO1	2	3	1	2	1
CO2	3	2	2	2	1
CO3	3	2	2	2	1
CO4	2	2	2	3	1
CO 5	2	1	1	2	1

Unit– I
Advantages and Disadvantages of Fluid control, Types of Hydraulic Fluids, physical, chemical and thermal properties of hydraulic fluids, selection of hydraulic fluid, fluid flow fundamentals. Hydraulic Pumps and Motors: Basic Types and constructions, ideal pump and motor analysis, Performance curves and parameters.

Unit– II
Hydraulic Control Valves- Valve configurations, general valve analysis, critical centre, open centre, three way spool valve analysis and Flapper valve analysis, pressure control valves, single and two stage pressure control valves, flow control valves, introduction to electro hydraulic valves.

Unit– III
Hydraulic Power Elements: Valve controlled motor, valve controlled piston, three way valve controlled piston, pump controlled motor, pressure transients in power elements.
Unit– IV
Characteristics of Pneumatics, Applications of Pneumatics, Basic Pneumatic elements, Pneumatic servomechanisms, pneumatic servo, ram equations, load sensitivity, method of stabilization, stabilization using auxiliary tanks. Some practical aspects of servo testing and design
Unit– V
Control of pressure and speed in Hydraulic and Pneumatic Systems, Fluidics: proportional amplifier, bistable amplifier, vortex amplifier, turbulence amplifier, impact modulator, Boolean algebra, fluid logics, manipulation of logic expressions, special circuits and sequential circuits. Application of fluid power systems for improvement of performance of turbomachines. Case studies
Topics to be taught by Industry Subject Expert :
Application of fluid power for turbomachinery and case studies

Suggested Reading:

1	Herbert E. Merritt, "Hydraulic Control Systems", John Wiley & Sons, 1991
2	D McCloy& H R Martin," The control of fluid power" Longman publications.
3	Anthony Esposito, "Fluid power with applications", Prentice Hall, 2002.
4	Arthur Akers, Max Gassman, Richard Smith, "Hydraulic Power System Analysis", Taylor and Francis Group, 2006.
5	John Pippenger& Tyler Hicks, "Industrial Hydraulics", 3rd edition McGraw Hill,
	Patrick J. Klette, Fluid Power Systems, Amer Technical Pub; 2nd edition, 2014

ME315	**VIBRATION ANALYSIS AND CONDITION MONITORING**					
(PROGRAM ELECTIVE– II)						
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60Marks	**CIE**		40Marks	

Course Objectives:	
On completion of this course, the student will be able to:	
1	Understand the theoretical basis for single and multi-degree freedom systems
2	Learn to derive the mathematical models for free and forced vibration systems
3	Understand the importance of various methods to solve multi degree freedom systems
4	Know the working principles of various condition monitoring equipment
5	Learn various methods of recording and displaying data

Course Outcomes:	
On completion of this course, the student will be able to:	
CO-1	Fully understand importance of vibrations in mechanical design of machine parts that operate under vibratory conditions.
CO-2	Write differential equation of motion of vibratory system and understand free and forced modes of vibration
CO-3	Obtain linear vibratory models of dynamic systems of varying complexity (SDOF,MDOF)
CO-4	Apply various condition monitoring techniques available in the literature.
CO-5	Classify and use various devices available to record interpret and understand the vibration data.

Program Articulation Matrix

Course outcome	**Program outcome**				
	PO1	**PO2**	**PO3**	**PO4**	**PO5**
CO1	3	3	1	1	1
CO2	2	2	2	2	1
CO3	2	2	3	2	1
CO4	2	2	2	3	1
CO 5	2	2	2	2	1

Unit– I
Causes and effects of vibration. Vibrations of Single Degree of freedom systems. Free, Damped and Forced vibrations.
Unit– II
Two Degree of freedom systems. Bending vibrations of two degree of freedom systems, Steady state and transient characteristics of vibration, vibration absorber and vibration isolation.

Unit– III
Multi degree of freedom systems: Dunkerley method, Rayleigh method, stodola method and holzers method. Modal analysis.
Unit– IV
Introduction to Condition Monitoring, Failure types, investigation and occurrences. Causes of failure, Vibration measuring instruments, vibration transducers, signal conditioning elements. Display and recording elements. Vibration meters and analyzers. Condition Monitoring through vibration analysis. Frequency analysis, Filters, Vibration signature of active systems, vibration limits and standards.
Unit– V
Contaminant analysis, SOAP and other contaminant monitoring techniques. Special vibration measuring techniques - Change in sound method, Ultrasonic measurement method, Shock pulse measurement, Kurtosis, Acoustic emission monitoring, Cepstrum analysis, Modal analysis, critical speed analysis, Shaft –orbit & position analysis. Application of Vibration analysis & Condition Monitoring in the design and development of turbomachines. Case studies
Topics to be taught by Industry Subject Expert :
Importance of vibration analysis and condition monitoring of turbomachinery , and case studies

Suggested Reading:

1	Rao S .S Mechanical Vibrations , 5th Edition, Prentice Hall, 2011
2	V.P.Singh, Mechanical vibrations, Dhanpat Rai Publications, 2015
3	Collacott, R.A., Mechanical Fault Diagnosis and Condition Monitoring, Chapman & Hall, London
4	John S. Mitchell, Introduction to Machinery Analysis and Monitoring, Penn Well Books, Penn Well Publishing Company, Tulsa, Oklahoma
5	J S Rao, Vibration condition monitoring of machines, CRC Press, 2000
	Nakra, B.C. Yadava, G.S. and Thuested, L., Vibration Measurement and Analysis, National Productivity Council, New Delhi

ME216	**FUELS AND COMBUSTION**					
	(PROGRAMELECTIVE– III)					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60Marks	**CIE**		40Marks	

Course Objectives:	
On completion of this course, the student will be able to:	
1	Understand solid, liquid and gaseous fuel properties
2	Analyse process and handling of fuels
3	Estimate stoichiometry relations in the combustion process
4	Understand the features of different types of burners and emissions
5	Analyse exhaust and flue gases

Course Outcomes:	
On completion of this course, the student will be able to:	
CO-1	Analyse combustion stability and the formation of pollutants in practical combustion devices
CO-2	Understand the fundamental theory of the combustion of non-premixed and premixed flames, laminar and turbulent flames, droplets and the theory of ignition
CO-3	Analyse the role of detailed chemical kinetics in combustion and the ability to calculate the equilibrium compositions of reacting systems.
CO-4	Understand pollution formation in practical devices such as internal combustion engines and gas turbines
CO-5	Design gasification techniques and equipment for solid and liquid fuels

Program Articulation Matrix

Course outcomes	**Program outcomes**				
	PO1	**PO2**	**PO3**	**PO4**	**PO5**
CO1	3	2	1	1	2
CO2	3	2	2	1	2
CO3	3	1	1	1	1
CO4	3	1	1	1	3
CO5	3	1	1	1	1

Unit– I

Introduction: General, Conventional energy resources, Solar energy, Nuclear power, Energy from biomass, Wind power, Tidal power, Geothermal energy, Energy survey for India, Rocket Fuels, Definitions, Units, Measures.

Unit– II

Solid Fuels: General, Biomass, Peat, Lignite or Brown Coal, Sub-bituminous Coal or Black Lignite, Bituminous Coal, Semi-anthracite, Anthracite, Cannel coal and Boghead coal, Natural coke (Jhama)/SLV fuel, Origin of coal, Composition of coal, Analysis and properties of coal, Action of heat on coal, Oxidation of coal, Hydrogenation of coal, Classification of coal. Processing of Solid Fuels: General Coal preparation, Storage of coal, Coal carbonization, Briquetting of solid fuels, Liquefaction of solid fuels.

Unit– III
Liquid Fuels : General, Petroleum, Origin of Petroleum, Petroleum production, Composition of petroleum, Classification of petroleum, Nature of Indian crude's, Petroleum processing, Important petroleum products, Properties and testing of petroleum and petroleum products, Petroleum refining in India, Liquid fuels from sources other than petroleum, Gasification of liquid fuels, Storage and handling of liquid fuels.
Unit– IV
Gaseous fuels: General, Types of gaseous fuels, Natural gas, Methane from coal mines, Producer gas, Water gas, Carburetted water gas, Complete gasification of coal, Underground gasification of coal, Coal gas, Blast furnace gas, Gases from biomass, Refinery gases, Liquefied petroleum gases (LPG), Oil gasification, Cleaning and purification of gaseous fuels.
Unit– V
Combustion Process (Stoichiometry and Thermodynamics):Combustion Stoichiometry: General, Examples, Rapid methods of combustion stoichiometry. Combustion Thermodynamics: General Combustion Process (Kinetics): Nature of combustion process, Types of combustion processes, Mechanism of combustion reaction, Spontaneous Ignition Temperature (SIT), Velocity of flame propagation, Limits of inflammability, Structure of flame, Flame stability, Kinetics of liquid fuel combustion, Kinetics of solid fuel combustion. Combustion Applications: General, Gas burners, Oil burners, Coal burning equipment.
Topics to be taught by Industry Subject Expert :
Industrial scenario in selecting fuels for steam generation in power plants. Application of fuels and combustion for improving the performance of turbomachines. Case studies

Suggested Reading:

1	Loftness, R.L., Energy hand book, New York, Van Nostrand
2	Wilson, P.J. and J.H. Wells, Coal, Coke and Coal Chemicals, New York : McGraw-Hill
3	Williams, D.A. and G. James, Liquid Fuels, London Pergamon
4	Gas Engineers Handbook, New York : Industrial Press
5	Minkoff, G.J., and C.F.H. Tipper, Chemistry of Combustion Reaction, London Butterworths
6	Samir Sarkar, Fuels & Combustion, Orient Long man

ME217	**ENERGY SYSTEMS AND MANAGEMENT**					
	(PROGRAMELECTIVE– III)					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60Marks	**CIE**		40Marks	

Course Objectives:	
On completion of this course, the student will be able to:	
1	To understand and compare global and Indian energy profile.
2	To compare global and Indian energy policies.
3	To analyze energy impact on environment.
4	Understand relationship between energy, ecology and environment.
5	Determine impact of International energy policy on national energy growth

Course Outcomes:	
On completion of this course, the student will be able to:	
CO-1	Understand the fundamentals of energy management
CO-2	Apply the principles of thermal engineering and energy management to improve the performance of thermal systems.
CO-3	Analyze the methods of energy conservation and energy efficiency for buildings, air conditioning, heat recovery and thermal energy storage systems.
CO-4	Design viable energy projects.
CO-5	Gain knowledge in carrying out energy auditing

Program Articulation Matrix

Course outcomes	**Program outcomes**				
	PO1	**PO2**	**PO3**	**PO4**	**PO5**
CO1	2	3	3	2	2
CO2	3	3	3	2	2
CO3	3	2	3	2	2
CO4	3	3	3	2	2
CO5	2	2	3	2	2

Unit– I

Introduction: Review of the concepts of Thermodynamics, Fluid Mechanics and Heat Transfer, Need for energy storage, Grid balancing: Supply and demand concept for energy management. Heat transfer equipment- Heat exchangers, Steam plant

Energy storage Methods and systems: Thermal, Electrical and Mechanical energy storage methods and systems, Energy saving in IC engines and Gas turbines.

Unit– II

Direct Energy Conversion methods: Magneto-hydrodynamic (MHO) power generation, Thermionic power generation, Thermoelectric power generation, Fuel cells, Hydrogen energy system

Heat recovery systems: Incinerators, regenerators and boilers

Unit– III
Energy Conservation: Methods of energy conservation and energy efficiency for buildings, air conditioning, heat recovery and thermal energy storage systems
Unit– IV
Energy Management: Principles of Energy Management, Energy demand estimation, Organising and Managing Energy Management Programs, Energy pricing
Unit– V
Energy Audit: Purpose, Methodology with respect to process Industries, Characteristic method employed in Certain Energy Intensive Industries, Economic Analysis: Scope, Characterization of an Investment Project and Case studies.

Suggested Reading:

1	Barun Kumar De, Energy Management audit & Conservation, Vrinda Publication, 2010, 2nd Edition.
2	Murphy, W. R., Energy Management, Elsevier, 2007, 1st Edition.
3	Doty, S. and Truner, W. C.,Energy Management Hand book, Fairmont Press, 2009, 7th edition.

ME124	**OPTIMIZATION TECHNIQUES**					
	(PROGRAMELECTIVE– III)					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60Marks	**CIE**		40Marks	

Course Objectives:	
On completion of this course, the student will be able to:	
1	To understand basic processes of physical phenomenon in industrial use
2	To learn various methods of modeling the process on scientific basis for linear and nonlinear
3	To solve for the unconstrained optimization of single and multi variables of the processes
4	To learn to solve the process by fraction or integer numbers for optimization
5	To solve by heuristic methods for optimization of the process

Course Outcomes:	
On completion of this course, the student will be able to:	
CO-1	Understand the basic modeling of the industrial processes
CO-2	Identify the mathematical modeling through simulation
CO-3	Analyse the simulation models with unbounded conditions
CO-4	Apply the un bounded models to multi objective purposes
CO-5	Formulate the model for a given situation/s

Unit– I
Simulation: Introduction, Types of Simulation, Simulation Models, Monte Carlo Simulation, Random Number, Pseudo Random Number, Mid-Square Method of generating Random Numbers, Application & Limitation, Application of Simulation to Inventory Control and Queuing Problem
Unit– II
Classical Optimization: Introduction; Unconstrained problems of maxima and minima, constrained problems of maxima and minima; Constraints in the form of equations – Lagrangian method; Constraints in the form of inequalities -Kuhn-tucker conditions.
Unit– III
Single Variable Non-Linear Unconstrained Optimization: Elimination methods: UniModel function-its importance, Fibonacci method & Golden section method. Interpolation methods: Quadratic & Cubic interpolation methods.
Unit– IV
Multi variable non-linear unconstrained optimization: Direct search methods–Univariant method, Pattern search methods –Powell's, Hook -Jeeves, Rosenbrock search methods. Gradient methods: Gradient of function& its importance, Steepest descent method, Conjugate direction methods: Fletcher-Reeves method & variable metric method.
Unit– V

Integer Programming: Introduction, Types of Integer Programming Problems, Gomory's Cutting Plane method. Branch and Bound method for all Integer Programming Problems & Mixed Integer Programming Problems. Stochastic Programming: Basic concepts of probability theory, random variables distributions- mean, variance, correlation, co variance, joint probability distribution. Stochastic linear programming: Chance constrained algorithm.
Topics to be taught by Industry Subject Expert :
Importance of Optimization techniques in turbomachinery and case studies

Suggested Reading:

1	S.S.Rao, Optimization Theory and Applications, 3 rd Edition, NAI Publishers, Hyderabad, 2010.
2	S.D.Sharma, Operations Research, Kedarnath and Co. Publishers, Meerut, 2020th Edition.
3	V. K. Kapoor, Operations Research, 2nd Edition, S. Chand, New Delhi, 2007.
4	Hamdy A.Taha, Operations Research, 10th Edition, Pearson Education, New York, 2019.
5	Bronson-Schaum Series, Operations Research, 2nd Edition, McGraw Hill, Singapore, 1997.
6	David Goldberg, Genetic Algorithms, 13th Edition, S Chand Publications, 1989.

ME311	**FINITE ELEMENT TECHNIQUES**					
	(PROGRAMELECTIVE– III)					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60Marks	**CIE**		40Marks	

Course Objectives:	
On completion of this course, the student will be able to:	
1	To familiarize students with the displacement-based finite element method for displacement and stress analysis and to introduce related analytical and computer tools.
2	To provides a bridge between hand calculations and numerical solutions for more complex geometries and loading states.
3	To study approximate nature of the finite element method and convergence of results are examined. It provides some experience with a commercial FEM code and some practical modeling exercises.

Course Outcomes:	
On completion of this course, the student will be able to:	
CO-1	Summarize the basics of finite element formulation
CO-2	Derive interpolation functions and characteristic matrices for different 1D, 2D and 3D elements.
CO-3	Apply the knowledge in solving one dimension and two dimensional static stress and dynamic analysis problems.
CO-4	Solve the steady state and transient heat transfer analysis using FEA.
CO-5	Analyze three dimensional stress analysis and fluid flow problems.

Program Articulation Matrix

Course outcome	**Program outcome**				
	PO1	**PO2**	**PO3**	**PO4**	**PO5**
CO1	3	2	2	2	1
CO2	3	3	2	2	1
CO3	3	3	2	2	1
CO4	3	3	2	2	1
CO 5	3	3	2	2	1

Unit– I

Introduction: Historical Background, General description of the finite element method, Mathematical Modeling of field problems in Engineering, Governing Equations, Discrete and continuous models, Boundary, Initial and Eigen Value problems, Weighted Residual Methods, Variational Formulation of Boundary Value Problems, Potential energy method, Rayleigh Ritz method, Galerkin's method of finite element formulation. Strain displacement relations, Stress strain relations, Interpolation models: Simplex, complex and multiplex elements, Linear interpolation polynomials in terms of local, natural and global coordinates for 1D, 2D, 3D Simplex Elements. Finite element equations, treatment of boundary conditions.

Unit– II
One-Dimensional Elements-Analysis of Bars and Trusses, Linear interpolation polynomials in terms of local coordinate's for 1D, 2Delements. Higher order interpolation functions for 1D quadratic and cubic elements in natural coordinates, Analysis of plane truss with number of unknowns not exceeding two at each node. Analysis of frames with two translations and a rotational degree of freedom at each node. Analysis of Beams: Element stiffness matrix for two noded, two degrees of freedom per node for beam element. Torsion of Shafts: Finite element formulation of shafts, determination of stress and twists in circular shafts.
Unit– III
Finite element modeling of two-dimensional stress analysis problems with constant strain triangles and treatment of boundary conditions. Two dimensional four noded iso-parametric elements and numerical integration. Plane stress, plane strain and axisymmetric problems, Body forces and temperature effects. Stress calculations, Plate and shell elements. Elements. Convergence requirements and geometric isotropy. Application to Field Problems, Thermal problems, Analysis of a uniform shaft subjected to torsion using Finite Element Analysis. Quadrilateral elements and Higher Order Elements.
Unit– IV
Steady state heat transfer analysis: One dimensional analysis of a fin, composite walls and two-dimensional conduction analysis of thin plate. Time dependent field problems: Application to one dimensional heat flow in a rod. Dynamic analysis: Formulation of finite element modeling of Eigen value problem for a stepped bar and beam. Evaluation of Eigen values and Eigenvectors.
Unit– V
Finite element formulation of three-dimensional problems in stress analysis. Fluid Flow: Flow through a porous medium, Flow through pipes of uniform and stepped sections, Flow through hydraulic networks. Finite Element formulation of an incompressible fluid. Potential flow problems Bending of elastic plates. Introduction to non-linear problems and Finite Element analysis software.
Topics to be taught by Industry Subject Expert:
Importance and applications of Finite Element methods in turbomachinery.

Suggested Reading:

1	Tirupathi R Chandraputla and Ashok.D.Belegundu, Introduction of Finite Element in Engineering, Prentice Hall of India
2	Rao S.S., The Finite Element Methods in Engineering, Pergamon Press
3	Segerland. L.J., Applied Finite Element Analysis, Wiley Publication
4	Reddy J.N., An Introduction to Finite Element Methods, McGraw Hill Compan
5	P.Seshu, Text book of Finite Element Analysis, PHI Learning Pvt. Ltd.

ME251	**TURBOMACHINARY LABORATORY**					
Pre-requisites	-		**L**	**T**	**P**	**C**
			-	-	2	1
Evaluation	**SEE**	-	**CIE**	50 Marks		

Course Objectives:	
On completion of this course, the student will be able to:	
1	To study the concepts, applications of the thermal engineering laboratory.
2	To demonstrate and conduct experiments, interpret and analyze data and report results of compressors, wind tunnel testing
3	To expose the students to the basic knowledge of thermal equipments and help them to develop experimental skills.

Course Outcomes:	
On completion of this course, the student will be able to:	
CO-1	Ability to prepare the model
CO-2	Critically evaluate the physics of the problem
CO-3	Ability to perform simulations/ experiment and understand the phenomenon
CO-4	Critically evaluate and interpret the results
CO-5	Prepare a well-organized record

Program Articulation Matrix

Course outcomes	**Program outcomes**				
	PO1	**PO2**	**PO3**	**PO4**	**PO5**
CO1	3	3	2	3	-
CO2	3	3	2	3	-
CO3	3	2	2	3	-
CO4	2	2	2	3	-
CO5	3	2	2	3	-

Experiment-I

1) Determination of static pressure distribution on a turbine blade surface at mid span on Low speed wind tunnel.
2) To Study downstream wake profile of a turbine cascade at mid span on Low speed wind tunnel.
3) To Study downstream wake profile of a compressor cascade at mid span on Low speed wind tunnel.
4) Study on performance of Centrifugal blower with forward swept blades.
5) Study on performance of Centrifugal blower with backward swept blades.
6) Study on performance of Centrifugal blower with radial blades.
7) Unsteady state Heat Transfer.
8) Thermal Conductivity of Liquid.
9) Experiments on Convergent Divergent Subsonic Nozzle.
10) To estimate the I-V and P-V characteristics of series and parallel combination of Solar Photovoltaic modules.
11) Workout power flow calculations of standalone Solar Photovoltaic system of DC and AC load with battery.

ME261	**SEMINAR**					
Pre-requisites	-		**L**	**T**	**P**	**C**
			-	-	2	1
Evaluation	**SEE**	-	**CIE**	50 Marks		

Course Objectives:	
On completion of this course, the student will be able to:	
1	Identify appropriate topic of relevance.
2	Update literature on technical articles of selected topic and develop comprehension.
3	Prepare a technical report.
4	Deliver presentation on specified technical topic.

Course Outcomes:	
On completion of this course, the student will be able to:	
CO-1	Identify and compare technical and practical issues related turbomachinery and related systems.
CO-2	Study different techniques adopted to solve the problem
CO-3	Understand usage of related techniques and softwares
CO-4	Investigate the procedure adopted and interpret the results and conclusions
CO-5	Document the findings

Program Articulation Matrix

Course outcomes	**Program outcomes**				
	PO1	**PO2**	**PO3**	**PO4**	**PO5**
CO1	3	3	3	2	2
CO2	3	3	3	2	2
CO3	2	3	3	2	2
CO4	2	2	2	2	1
CO5	2	2	2	2	1

Seminar topics may be chosen by the students with advice from the faculty members and the student shall read further relevant articles in the domain.

The seminar must be clearly structured and the power point presentation shall include following aspects:

1. Introduction to the field
2. Literature survey
3. Consolidation of available information
4. Objectives and Methodology
5. Results and Discussions& Summary
6. Conclusions
7. References

Each student is required to:

1. Deliver the seminar for a maximum duration of 30 minutes, where the presentation should be for 20 minutes in PowerPoint, followed by Question and Answers session for 10 minutes.

2. Submit the detailed report of the seminar in spiral bound in a précised format as suggested by the Department.

Guidelines for awarding marks		
S. No.	**Description**	**Max. Marks**
1	Contents and relevance	10
2	Presentation skills	10
3	Preparation of PPT slides	05
4	Questions and answers	05
5	Report in a prescribed format	20

Note:

1. The seminar presentation should be a gist of at few research papers from Peer-reviewed or UGC recognised journals.
2. The seminar report should be in the following order: Background of work, literature review, techniques used, prospective deliverables, discussion on results, conclusions, critical appraisal and reference.
3. At least two faculty members will be associated with the seminar presentation to evaluate and award marks.
4. Attendance of all the students for weekly seminar presentations is compulsory.

SEMESTER-II

ME204	**HEAT TRANSFER AND HEAT EXCHANGERS IN POWER PLANTS**					
(PROGRAM CORE-IV)						
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60Marks	**CIE**		40Marks	

Course Objectives:	
On completion of this course, the student will be able to:	
1	Account for the consequence of heat transfer in thermal analyses of engineering systems.
2	Develop solutions for transient heat and Obtain numerical solutions for conduction and radiation heat transfer problems.
3	Evaluate heat transfer coefficients for natural convection and forced convection.
4	Analyze heat exchanger performance
5	Analyze heat exchanger performance by using the method of heat exchanger effectiveness and Calculate radiation heat exchange

Course Outcomes:	
On completion of this course, the student twill be able to:	
CO-1	Formulate 2D heat conduction problems in rectangular, cylindrical and spherical coordinate system by transforming the physical system into a mathematical model.
CO-2	Compute boundary layer for laminar and turbulent flows and convective heat transfer coefficients
CO-3	Solve problem in radiation heat transfer and numerical methods.
CO-4	Analyse the mechanism which is involved in boiling and condensation
CO-5	Compute different types of heat exchangers used in an Industries and that leads to design heat exchanges

Program Articulation Matrix

Course outcomes	**Program outcomes**				
	PO1	**PO2**	**PO3**	**PO4**	**PO5**
CO1	3	2	2	2	1
CO2	2	3	3	2	1
CO3	2	2	3	2	1
CO4	2	2	2	3	1
CO5	2	2	2	3	1

Unit-I

Conduction: Two-dimensional steady state problems – Cartesian and cylindrical geometries. General unsteady state heat conduction equation in cylindrical and spherical co-ordinates. Periodic and non-periodic temperature variations within a semi-infinite solid within infinite wall. Extended Surfaces (Fins): Heat transfer from a straight fin (Plate) of a uniform cross section, Error in measurement of temperature in a thermometer well, Fin efficiency, Applications.

Unit-II
Convection: Approximate integral boundary layer analysis. Heat transfer in the laminar flow inside smooth tubes. Analogy between momentum and heat transfer in turbulent flow over a plane surface and turbulent flow in a tube. Empirical correlations – free convection (vertical and horizontal plates).
Unit-III
Radiation: Enclosures with black surfaces, Enclosures with gray surfaces. Numerical Methods– finite difference techniques Gas radiation.
Unit-IV
Boiling and condensation: Boiling: Boiling phenomenon, Boiling curve, Mechanism of nucleate boiling, Stable film boiling, Forced convection boiling. Condensation: Condensation phenomenon, Film Condensation on a vertical surface, Condensation outside a horizontal tube or a tube bank, Condensation inside a horizontal tube. Drop wise Condensation. Introduction to two-phase flow: Simple momentum and energy equations.
Unit-V
Heat Exchangers: Parallel flow, counter flow and cross flow heat exchangers, multi-pass shell and tube heat exchangers and design. Plate type of heat exchangers, and Compact Heat Exchangers. Power plant heat exchangers: Condensers, Feed Water Heaters, Evaporators, Dearators, Economizer, Air Pre heaters, and their design considerations. Principles of simultaneous heat and mass transfer. Analysis of cooling towers. Case studies of heat transfer related problems in Power Plant Boilers and Turbines.

Suggested Reading:

1	Frank Kreith and S. Bohn, Principles of Heat Transfer, Harper and Roks Publishers, New York
2	Glen Myers, Analytical Method in Conduction Heat Transfer, McGraw Hill
3	W.M. Kays, Convective Heat and Mass Transfer, Tata McGraw Hill Publishing Co. Ltd.
4	J.P. Holman, Heat Transfer, McGraw-Hill Book
5	Binay K. Dutta, Heat Transfer, Prentice Hall of India, 2001.

ME205	**DESIGN OF STEAM TURBINES**					
(PROGRAM CORE-V)						
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60Marks	**CIE**		40Marks	

Course Objectives:	
On completion of this course, the student will be able to:	
1	Understand and know the requirements for a Thermal Power Plant and turbines
2	Study and learn the processes and cycles followed in steam turbines
3	Identify, formulate and solve problems related to turbines
4	Become familiar with the mechanical design, configurations, application ranges and constraints for steam turbines.
5	Learn to design turbine components

Course Outcomes:	
On completion of this course, the student will be able to:	
CO-1	Apply thermodynamic concepts to analyze turbo machines.
CO-2	Analyze power plant and propulsion cycles.
CO-3	Analyze impulse and reaction turbo machines for energy transfer.
CO-4	Design steam turbine components.
CO-5	Evaluate the performance of turbo machine components

Program Articulation Matrix

Course outcomes	**Program outcomes**				
	PO1	**PO2**	**PO3**	**PO4**	**PO5**
CO1	3	2	3	2	2
CO2	3	2	3	2	2
CO3	3	2	3	2	2
CO4	3	2	3	2	2
CO5	3	2	3	2	2

Unit– I
Working principles of steam turbines. Flow through impulse and reaction steam turbine stage. Theoretical steam turbine cycle and methods of improving cycle efficiency.
Unit– II
Flow analysis in steam nozzles and effect of back pressure. Design and testing of converging–diverging nozzle. Effect of area ratio on the performance of the nozzle.
Unit– III
Optimum blade speed ratio and two stage impulse wheel. Blade and stage efficiencies for multistage steam turbines. Vortex flow and mixed flow turbines. Losses in steam turbines. Design of steam turbine blade and performance at varying loads.

Unit– IV
Design and construction of steam turbine rotor. Disc of constant strength. Stress in steam turbine rotors and blades. Material for rotor and blades.
Unit–V
Blade attachment techniques. Critical speeds and balancing of rotors, speed regulation of turbines. Static and dynamic balancing of turbogenerator sets. Applications of steam turbines.
Industrial expert topic: Case studies related to turbine applications, problems encountered during functioning and their rectification.

Suggested Reading:

1	W.J. Kearton, Steam Turbine Theory And Practice, Seventh Edition, CBS Publishers, 2004
2	P Shlyakhin, Steam Turbines: Theory and Design, University Press of the Pacific 2005
3	Heinz P. Bloch, Murari Singh, Steam Turbines: Design, Application, and Re-Rating, Second Edition, McGraw Hill Professional, 2008
4	Murari Singh, Blade Design and Analysis for Steam Turbines, McGraw-Hill Education, 2011
5	Hermann Wilda, Charles Salter, Steam Turbines: Their Theory and Construction, Merchant Books, 2007
6	H H Harrison, Model Steam Turbines; How to Design and Build Them, Franklin Classics, 2018

ME206	**CASCADE AERODYNAMICS**					
(PROGRAM CORE-VI)						
Pre-requisites	-		**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60Marks	**CIE**		40Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	To provide information regarding the behavior of compressible fluid flow
2	To impart knowledge regarding the difference between subsonic and supersonic flow
3	To Estimate flow over flying vehicles at subsonic and supersonic speeds
4	Understand the influence of compressibility and to distinguish between the flow regime
5	Apply compressibility corrections for flow in C-D passages and analyze the compressible flow field over an airfoil and finite wings

Course Outcomes:	
On completion of this course, the student will be able to:	
CO-1	Understand turbine and compressor airfoil blades nomenclature.
CO-2	Analyze the flow over airfoil and Calculate airfoil profile coordinates for NACA Series blades.
CO-3	Evaluate forces acting on turbine airfoil blades and understand loss mechanisms leading to their estimation using correlations.
CO-4	Evaluate forces acting on compressor airfoil blades and understand loss mechanisms leading to their estimation using correlations.
CO-5	Application of Finite Difference Techniques for studying flow through variable area flow passages in turbomachines.

Program Articulation Matrix

Course outcomes	**Program outcomes**				
	PO1	**PO2**	**PO3**	**PO4**	**PO5**
CO1	1	1	1	2	1
CO2	3	3	1	1	1
CO3	3	3	1	3	1
CO4	3	3	1	3	1
CO5	3	3	3	3	2

Unit– I
Airfoil blade geometry. Blade terminology – leading and trailing edges, flow angles, blade angles, camber line, chord line, solidity, space to chord ratio, aspect ratio, Comparison of turbine and compressor blade/ cascade profiles.
Unit– II

Fundamental Theory of Airfoils - flow around an aerofoil, pressure distribution around airfoil and lift generation. NACA series of airfoils –Calculation of coordinates of airfoils for NACA Four-Digit Series and NACA Five-Digit Series- Advantages and Disadvantages of NACA Series Airfoils and their Applications.
Unit– III
Turbine cascade analysis – evaluation of axial, tangential, lift and drag forces. Relations for lift, drag and pressure coefficients. Losses in turbine cascade/blade passages – profile, annulus, secondary and tip clearance losses. Correlations for estimation of losses.
Unit– IV
Compressor cascade analysis – evaluation of axial, tangential, lift and drag forces. Relations for lift, drag and pressure coefficients. Losses in compressor cascade/blade passages – profile, annulus, secondary and tip clearance losses. Correlations for estimation of losses.Effects of flow and geometrical parameters on cascade performance.
Unit–V
Application of finite difference techniques for study of flow phenomena – first & second order accuracy relations for forward, rearward & central difference relations. Two dimensional supersonic flow through a turbo machine passage – transformation of physical plane into computational plane, governing equations, primitive variables, flux variables, application of Mack Cormack's finite difference method, predictor – corrector approach for obtaining numerical solutions.
Topics to be taught by Industry Subject Expert :
Case studies related to application of cascade aerodynamics in turbomachinery. Importance of cascade aerodynamics in simulation of turbomachinery problems and case studies.

Suggested Reading:

1	J.P.Gostelow, Cascade Theory, Pergamon Press, New York
2	Charles E. Dole & James E. Lewis, Flight Theory and Aerodynamics, John Wiley and Sons 2000
3	J.H. Horlock, Axial Flow Compressors and Turbines, Krieger Publishing Company
4	Peter Jonathan Baddoo, Analytic Solutions for Flows Through Cascades, Springer, 2020
5	O. C. Zienkiewicz, R. L. Taylor, The Finite Element Method: Fluid Dynamics, John Wiley & Sons Inc,2000

ME218	**COMPUTATIONAL FLUID DYNAMICS**					
(PROGRAMELECTIVE– IV)						
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60Marks	**CIE**		40Marks	

Course Objectives:	
On completion of this course, the student will be able to:	
1	Learn the basic equations of fluid flow
2	Understand the major theories, approaches and methodologies used in CFD
3	Build up the skills in the actual implementation of CFD methods (e.g. boundary conditions, turbulence modeling etc.) in using commercial CFD codes
4	Gain experience in the application of CFD analysis to real engineering designs.

Course Outcomes:	
On completion of this course, the student will be able to do:	
CO-1	Understand the governing equations of different types of fluid flow systems, averaging procedure of turbulent flow properties
CO-2	Classify second order partial differential equations, formulate finite difference equations based on accuracy, type of differencing and should be able to analyse their stability
CO-3	Discretise the problem domain
CO-4	Apply FDM and solve equations using numerical methods
CO-5	Apply Finite volume method for basic equations of heat transfer and fluid flow problems.

Program Articulation Matrix

Course outcomes	**Program outcomes**				
	PO1	**PO2**	**PO3**	**PO4**	**PO5**
CO1	3	2	2	2	-
CO2	3	2	1	-	-
CO3	3	2	1	-	-
CO4	3	3	3	2	1
CO5	3	3	3	2	2

Unit-I
Review of basic equations of fluid dynamics: Continuity, Momentum and Energy equations, Navier Stokes equations, Reynolds and Favre averaged N – S equations. Differential equations for steady and unsteady state heat conduction. Differential equations for diffusion. Introduction to turbulence, Turbulence models-mixing length model, k-ε turbulence Model.
Unit-II
Classification of PDEs – Elliptic, parabolic and hyperbolic equations. Initial and boundary value problems. Concepts of Finite difference methods – forward, backward and central difference. Errors, Consistency, Stability analysis by von Neumann. Convergence criteria.

Unit-III
Grid Generation- Types of grid O,H,C. Coordinate transformation, algebraic methods. Unstructured grid generation
Unit-IV
Finite difference solutions-Parabolic PDEs – Euler, Crank Nicholson, Implicit methods, Elliptic PDEs –Jacobi, Gauss Seidel, ADI, methods. FD- solution for Viscous incompressible flow using Stream function –Vorticity method & MAC method.
Unit-V
Introduction to Finite volume method. Finite volume formulations for diffusion equation, convection diffusion equation. Solution algorithm for pressure velocity coupling in steady flows. Use of Staggered grids SIMPLE Algorithm. Application of CFD in the design and development of turbomachines. Case studies
Topics to be taught by Industry Subject Expert :
Importance of CFD in simulation of turbomachinery problems and case studies.

Suggested Reading:

1	PradipNiyogi, Chakrabartty SK, Laha M.K., "Introduction to Computational Fluid Dynamics", Pearson Education, 2005.
2	Muralidhar K, Sundararajan T, "Computational Fluid flow and Heat transfer", Narosa Publishing House,2003.
3	Chung, T J, "Computational Fluid Dynamics", Cambridge University Press, 2002.
4	John D Anderson, "Computational Fluid Dynamics", McGraw Hill, Inc., 1995
5	Patankar, S.V, "Numerical Heat transfer and Fluid flow", Hemisphere Publishing Company, New York,1980.
6	H. Versteeg and W. Malalasekera, An Introduction to Computational Fluid Dynamics: The Finite Volume Method, PHI; 2nd edition, 2007

ME219	**COMBUSTION AND EMISSION CONTROL**					
	(PROGRAMELECTIVE– IV)					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60Marks	**CIE**		40Marks	

Course Objectives:	
On completion of this course, the student will be able to:	
1	Analyze the combustion process in general for development of new kind of engines.
2	Relationship between the chemical combustion and pollutants due to combustion
3	The fire or heat generated by the combustion is controlled by understanding flame behaviour.
4	Readjust the fuel emissions by changing combustion to suit safety standards
5	Understanding the modus operandi of pollution testing machines

Course Outcomes:	
On completion of this course, the student will be able to do:	
CO-1	Understand the concepts of combustion phenomena in IC Engines and Gas Turbines.
CO-2	Apply the knowledge of adiabatic flame temperature in the design of combustion devices.
CO-3	Identify the phenomenon of flame stabilization in laminar and turbulent flames.
CO-4	Analyse the possible harmful emissions and measure as per the legislation standards.
CO-5	Try new fuels and study their combustion process for research and development.

Program Articulation Matrix

Course outcomes	**Program outcomes**				
	PO1	**PO2**	**PO3**	**PO4**	**PO5**
CO1	1	3	2	4	1
CO2	3	3	1	2	3
CO3	2	1	1	1	2
CO4	3	1	3	2	3
CO5	2	2	1	2	3

Unit-I

Combustion Principles: Combustion – Combustion equations, heat of combustion - Theoretical flame temperature – chemical equilibrium and Dissociation -Theories of Combustion - Flammability Limits - Reaction rates – Laminar and Turbulent Flame Propagation in Engines. Introduction to spray formation and characterization.

Unit-II

Combustion in S.I. Engines: Stages of combustion, normal and abnormal combustion, knocking, Variables affecting Knock, Features and design consideration of combustion chambers. Flame structure and speed, Cyclic variations, Lean burn combustion, Stratified charge combustion systems. Heat release correlations.

Combustion In C.I. Engines: Stages of combustion, vaporization of fuel droplets and spray formation, air motion, swirl measurement, knock and engine variables, Features and design considerations of combustion chambers, delay period correlations, heat release correlations, Influence of the injection system on combustion, Direct and indirect injection systems.

Unit-III
Combustion in Gas Turbines: Flame stability, Re-circulation zone and requirements - Combustion chamber configurations, Cooling, Materials. **Pollutant Emissions from IC Engines:** Introduction to clean air, Pollutants from SI and CI Engines: Carbon monoxide, UBHCs, Oxides of nitrogen (NO-NOX) and Particulate Matter, Mechanism of formation of pollutants, Factors affecting pollutant formation. Measurement of engine emissions-instrumentation, Pollution Control Strategies, Emission norms-EURO and Bharat stage norms. Effect of emissions on environment and human beings.Brief treatment on harmful emissions from Gas Turbines, Gas turbine-NOx control (DLE - Dry Low Emission).
Unit-IV
Control Techniques for Reduction of Harmful Emissions from IC Engines: Emission control measures for SI and CI engines and gas turbines. Design modifications – Optimization of operating factors – Fuel modification – Evaporative emission control - Exhaust gas recirculation – SCR – Fumigation – Secondary Air injection – PCV system – Particulate Traps-Thermal reactors – Catalytic converters – Catalysts – Use of unleaded petrol-brief treatment.
Unit-V
Test Procedure, Instrumentation & Emission Measurement: Definition of Vehicle Driving Cycle-Test procedures INDIAN DRIVING CYCLE (IDC) – ECE Test cycle – FTP Test cycle – NDIR analyser – Flame ionization detector – Chemiluminescent analyser – Continuous Volume Sampling-Dilution tunnel – Gas chromatograph – Smoke meters. Case studies
Topics to be taught by Industry Subject Expert :
Case studies combustion of fuels and emission control measures.

Suggested Reading:

1	John.B. Heywood ,Internal Combustion Engine Fundamentals, McGraw Hill Co., 2018, II Edition.
2	Cohen, H, Rogers, G, E.C, and Saravanamuttoo, H.I.H., Gas Turbine Theory, Pearson, Pearson, 2019,7th Edition.
3	Stephen, R. Turns., Introduction to Combustion, McGraw Hill, 2005.
4	B.P. Pundir B P Engine Emissions Fundamentals and Advances in Control, Narosa Publications. 2017, 2/E
5	Warnatz, Ulrich Maas and Robert W. Dibble Combustion: Physical and Chemical Fundamentals, Modelling and Simulation, Experiments, Pollutant Formation, Springer, 2012.

ME220	**TURBULENT FLOWS**					
(PROGRAMELECTIVE– IV)						
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60Marks	**CIE**		40Marks	

Course Objectives:	
On completion of this course, the student will be able to:	
1	Understand the phenomenon of turbulence
2	Learn the time averaging procedure for the properties
3	Describe various turbulent models

Course Outcomes:	
On completion of this course, the student will be able to do:	
CO-1	Understand the origin, statistical nature and applications of turbulence.
CO-2	Employ the statistical methods to derive Reynolds averaged Navier-Stokes (RANS) equations.
CO-3	Analyze momentum and heat transport in free-shear and wall bounded flows through RANS equations
CO-4	Design and analyze the performance of Turbo machines for engineering applications and Understand the energy transfer process in Turbo machines and governing equations of various forms.
CO-5	Selecting the turbulence model to analyze various industrial complex flows in thermal applications.

Program Articulation Matrix

Course outcomes	**Program outcomes**				
	PO1	**PO2**	**PO3**	**PO4**	**PO5**
CO1	3	3	3	1	1
CO2	2	3	3	2	1
CO3	3	2	2	2	1
CO4	3	2	1	2	1
CO5	2	2	1	3	1

Unit-I

Introduction: The nature of turbulence, Consequences of Turbulence, Origin of turbulence, Examples of Laminar-Turbulent Transition, Turbulent diffusivity, Laminar and Turbulent Boundary layers, Length scales of turbulent flows, Turbulent flows in industrial applications.
Statistical description of turbulence: Random nature of turbulence, Characterization of random variables, Two-point correlation functions and spectra, Probability density functions and averaging.

Unit-II
Governing equations of Turbulent Transport: Continuum hypothesis, Eulerian and Lagrangian fields, Elements of Kinetic Theory of gases, Continuity, Momentum and Scalar transport equations, Role of Pressure, Rates of Strain and Rotation, Vorticity dynamics and vortex stretching, The Reynolds decomposition, Equations of Mean Flow (Momentum and Scalar transport), Reynolds Stresses, Gradient diffusion and Turbulent viscosity hypothesis, Estimation of Reynolds Stresses, Turbulent heat transfer.
Unit-III
The scales of turbulent motion: Energy Cascade and Kolmogorov Hypothesis, Fourier modes, Velocity Spectra, Spectral view of energy cascade, Limitations, Shortcomings and refinements.
Unit-IV
Free-shear flows: Plane shear flows in Turbulent wakes, jets and mixing layers, Streamwise and cross-stream momentum equations, Momentum integral and momentum thickness, turbulent energy budget for wakes, jets and mixing layers, Thermal plumes.
Wall-bounded flows: Turbulent boundary layers on smooth wall, Inertial sublayer, Core region, Logarithmic frictional law, Viscous sublayer, Turbulent flow in pipe, Experimental data on pipe flow, flow over rough surfaces, planetary boundary layers, Downstream development of turbulent boundary layers, Turbulent scalar transport in wall bounded flows.
Unit-V
Modelling and Simulation of turbulent flows: History of turbulence modelling, Reynolds-Averaged Navier Stokes Equations, The Closure Problem, Boussinesq Eddy-viscosity approximation, Mixing length hypothesis, Algebraic Models, One-equation and two-equation models, Application of various turbulence models to free shear flows and wall bounded flows, Near wall treatment, Direct Numerical Simulation (DNS), Large Eddy Simulation (LES) and related techniques. Application of turbulent flows in design and development of turbomachines. Case studies
Topics to be taught by Industry Subject Expert :
Importance of turbulent flows in turbomachinery and case studies

Suggested Reading:

1	Stephen B. Pope, Turbulent Flows, Cambridge University Press
2	Biswas, G., and V. Eswaran, Turbulent flows: Fundamentals, experiments and modeling, CRC Press, 2002.
3	Hendrik Tennekes and John L. Lumley, A First Course in Turbulence, MIT Press
4	Peter Davidson, Turbulence: An Introduction for Scientists and Engineers, Cambridge University Press, Oxford University Press

ME221	**FLOW INDUCED VIBRATIONS**					
(PROGRAMELECTIVE– IV)						
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60Marks	**CIE**		40Marks	

Course Objectives:	
On completion of this course, the student will be able to:	
1	Understand the problems that coupling with a fluid for both quiescent and flowing flow.
2	Understand the current state-of-the-art in the area of flow induced vibrations
3	Classify the mechanisms for flow-induced vibration and explain the qualitative differences between these mechanisms
4	Analyse theoretically a single and millidegree of freedom aeroelastic systems
5	Assess the impact of FSI and FIV to a particular problem.

Course Outcomes:	
On completion of this course, the student will be able to do:	
CO-1	Understand problems coupling with a fluid
CO-2	Analyses non-dimensional variables and induced vibrations.
CO-3	Understand the mechanisms for flow-induced vibration and explain the qualitative differences between these mechanisms
CO-4	Analyse theoretically a single and millidegree of freedom aeroelastic systems
CO-5	Assess the impact of FIV to a particular problem.

Program Articulation Matrix

Course outcomes	**Program outcomes**				
	PO1	**PO2**	**PO3**	**PO4**	**PO5**
CO1	3	2	1	1	1
CO2	3	3	1	1	1
CO3	3	2	1	1	1
CO4	3	3	1	2	1
CO5	3	3	1	1	1

Unit-I
Single degree system with external excitation. Two-degree System, Modal analysis, Principal coordinates.
Unit-II
Non dimensional variables, Vortex induced vibrations, Vortex wake of a stationary cylinder, Strouhal's number, Wake oscillatory model, Correlation model, Reduction of vortex induced vibrations.

Unit-III
Stall flutter, Stability of one degree and two-degree freedom systems. Response of one degree and two degree of freedom systems, Galloping of a beam and cable and reduction of galloping vibrations.
Unit-IV
Vibrations induced by oscillatory flow, solution of linearised equations, Oscillatory flow with mean zero flow and with mean flow, Sound induced by vortex shedding.
Unit-V
Vibrations of pipe containing fluid flow, Vibrations of cantilever and pinned-pinned pipe, Pipe whip. Application of Flow induced vibrations in the Design and development of turbomachinery and case studies.
Topics to be taught by Industry Subject Expert :
Importance of flow induced vibrations in turbomachinery and case studies

Suggested Reading:

1	Robert D. Blevines, Flow Induced Vibration, Krieger Publishing Company, 2006
2	Tomomichi Nakamura, Flow Induced Vibrations: Classifications and Lessons from Practical Experiences, Elsevier Science,2008
3	A. Zukowskus, Fluid Dynamics and Flow-induced Vibrations of Tube Banks, Taylor & Francis Inc
4	E. Naudascher,Flow-Induced Vibrations: An Engineering Guide, Dover Publications Inc, 2005
5	M.K. Au-Yang, Flow-Induced Vibration of Power and Process Plant Components: A Practical Workbook, ASME, 2001

ME222	**ADVANCED ENERGY SYSTEMS**					
	(PROGRAMELECTIVE – V)					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60Marks	**CIE**		40Marks	

Course Objectives:	
On completion of this course, the student will be able to:	
1	To acquaint with energy systems and their basic principles.
2	To acquire knowledge on various advanced energy conversion equipments
3	To understand the principles of renewable energy technologies.
4	To study the working principle, construction of power generation from non-conventional sources of energy.

Course Outcomes:	
On completion of this course, the student will be able to do:	
CO-1	Identify the need and promise of simultaneously alternative and "clean" energy technologies such as renewable energy systems
CO-2	Expose to the diversity of beneficial applications currently utilizing renewable energy
CO-3	Introduce societal catalysts and challenges regarding renewable energy Implementation
CO-4	Evaluate the performance of thermal systems using of energy management principles
CO-5	Explore the utilization of renewable energy within developing or developed regions

Program Articulation Matrix

Course outcomes	**Program outcomes**				
	PO1	**PO2**	**PO3**	**PO4**	**PO5**
CO1	3	1	1	1	1
CO2	3	1	1	1	1
CO3	3	1	1	1	1
CO4	3	2	1	2	1
CO5	3	3	2	3	1

Unit-I
Solar Energy: Solar radiation–measurement, collection and storage, Solar Thermal Systems, Design of flat plate and parabolic concentrating collectors, Solar power plants. Photo voltaic power systems. Application of SPV.

Unit–II
Wind Energy: Estimation of wind energy potential. Horizontal and Vertical axis wind turbine rotors. Aerodynamic design considerations for wind rotor blades. Wind electric generators-operation and control. Aero generators for battery charging.
Unit–III
Biomass Energy: Sources of biomass. Biomass for Energy production. Methane production. Biomass energy conversion technologies. Use of Biomass gasifier, Types of gasifiers. Biomass Power generation using agricultural residues. Introduction of Hybrid energy systems.
Unit-IV
Waste Heat Recovery: Principles and Devices - Regenerators and Recuperators. Analysis of heat recovery systems. Design of waste heat recovery boilers. Combined cycle power plants based on waste heat recovery.
Unit-V
Fuel Cell Technology: Introduction, Classification of fuel cells, Operating principles, Thermodynamic Aspects of Electrochemical Energy Conversion, Electrochemical kinetics, Performance of fuel cells, fuel cell components - Alkaline Fuel Cells, (AFC), Solid Oxide Fuel Cells (SOFC), Proton Exchange Membrane Fuel Cells (PEMFC), Characteristics of fuel cells. Case studies
Topics to be taught by Industry Subject Expert :
Importance of various tapes of energy systems in turbomachinery and case studies

Suggested Reading:

1	J.A. Duffire and W.A. Beckmen, Solar Energy Thermal Processes, John Wiley & Sons Inc, New York, 2006
2	Paul Gipe, Wind Energy Comes of Age, John Wiley & Sons Inc, New York
3	N.H Ravindranath and D O Hall, Bio Mass, Energy and Environment, Oxford University Press
4	Robert Goldstick, Principles of waste heat recovery, Fairmont Press
5	J. Larminie and A. Dicks, Fuel Cell Systems Explained, 2nd Edition, Wiley, 2003

ME223	**TWO PHASE FLOW AND HEAT TRANSFER**					
(PROGRAMELECTIVE– V)						
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60Marks	**CIE**		40Marks	

Course Objectives:	
On completion of this course, the student will be able to:	
1	Introduce and describe the processes in two-phase
2	Understand and model the behaviour of two-phase thermal-hydraulic system components**.**
3	Demonstrate the ability to model multiphase flows
4	Perform fundamental analysis of multiphase flow system
5	Demonstrate linkage between mass transfer and heat flow

Course Outcomes:	
On completion of this course, the student will be able to do:	
CO-1	Demonstrate the ability to model multiphase flows
CO-2	Perform fundamental analysis of multiphase flow system
CO-3	Link between mass transfer and heat flow
CO-4	Understand the physical phenomena and specific models that can be used as an aid in two phase flow and heat transfer
CO-5	Design and analyse the combustion systems, nuclear and other reactors, and heat transfer in industrial processes commonly found in plants

Program Articulation Matrix

Course outcomes	**Program outcomes**				
	PO1	**PO2**	**PO3**	**PO4**	**PO5**
CO1	2	3	1	3	1
CO2	3	2	1	2	1
CO3	3	3	1	2	1
CO4	3	3	1	3	1
CO5	3	3	1	3	1

Unit-I

Introduction: Fundamentals of heat and mass transfer. Generating phase diagrams in Engineering Equation Solver (EES) software. Introduction to mass transport. Gas-Liquid interfacial phenomena. Interfacial waves on thin films, jets, jet breakup and bubble growth

Unit-II

Two-phase mixtures: Particles and films, Homogeneous vs. separated flow model. Two-phase flow regimes. Two-phase modelling – one-dimensional. Flow regime-based pressure drop prediction. Two-phase modelling – multi-dimensional.

Unit-III
Drift Flux Model : Drift Flux model and void fraction prediction. Flow regimes and interfacial area. Pressure drop comparison of macro- and micro-scale heat exchangers. Two-phase flow in small passages.
Unit-IV
Nucleate boiling: Electronics cooling via immersion. Film boiling, Flow boiling, Flow regime-based heat transfer model, Flow regimes and impact on flow boiling. **CHF and post-CHF heat transfer:** Analysis of the physical basis for CHF hypotheses. Flow boiling in small passages, CHF in small passages. Two-phase microchannel cold plate for electronics thermal management
Unit-V
Fundamentals of condensation: Internal flow condensation. Condensation on jets and droplets. Choking in two-phase flow. Atomizer: Critical two-phase flow models**.** Spray formation and Spray evaporation rate. Single droplet behavior. Instabilities - droplet breakup Atomization of the jet in cross-flow. Instabilities - droplet breakup. Spray/Wall impingement Spray cooling thermal management of high heat flux sources. Spray/wall impingement
Topics to be taught by Industry Subject Expert :
Importance and application of two phase flow and heat transfer in turbomachinery, and case studies

Suggested Reading:

1	Mostafa Ghiaasiaan S, Two-Phase Flow, Boiling, and Condensation 1st Edition, Cambridge University Press, Cambridge, 2008
2	Nellis G. F. and Klein S. A., Heat Transfer 1st Edition, Cambridge University Press, Cambridge, 2008
3	P B Whalley, Two-Phase flow and heat transfer, Atlantic, 2008
4	John G Collier, Two- Phase Flow and Heat Transfer in the Power and Process Industries McGraw-Hill Companies
5	Graham B Wallis , One-Dimensional Two-Phase Flow, Dover Publications Inc ,2020

ME224	**DESIGN OF PUMPS AND COMPRESSORS**					
(PROGRAMELECTIVE– V)						
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60Marks	**CIE**		40Marks	

Course Objectives:	
On completion of this course, the student will be able to:	
1	Understand the principle involved in the operation of centrifugal and positive displacement pumps
2	Understand the principle involved in the operation of compressors
3	Identify the function of various components in pumps and compressors
4	Identify the parts of pumps, compressors and mechanical drives, and troubleshoot pumps, compressors and mechanical drives.
5	Design suitable pumps and compressors for different types of liquids in industry

Course Outcomes:	
On completion of this course, the student will be able to do:	
CO-1	Apply thermodynamic concepts to analyze pumps and compressors.
CO-2	Design pumps and compressor components.
CO-3	Evaluate the performance of pumps and compressors
CO-4	Understand the Operation and maintenance of pumps and compressors
CO-5	Evaluate the characteristics of pumps an compressors

Program Articulation Matrix

Course outcomes	**Program outcomes**				
	PO1	**PO2**	**PO3**	**PO4**	**PO5**
CO1	3	3	1	1	2
CO2	3	3	2	1	2
CO3	3	3	2	1	3
CO4	3	1	1	1	1
CO5	3	3	1	1	2

Unit-I
Introduction to pumps and compressors. Characteristics of working fluids, Fluid mechanics concepts and governing laws of fluid flow.
Unit-II
Pumps – various components and their functions. Classification of pumping systems – based on the applications and working fluids. Design of pumps – data required for the design of pump and design calculations. Selection of the drive – Types of drives, their behaviour and advantages, Selection of the pumps– types of pumps. Selection of piping and other components. Development of a schematic layout of the piping system.

Unit-III
Operation and maintenance–installation of pumping system. Testing of the pumping systems–Various methods based on the working fluid, drive and pump etc., Maintenance of the pumps – Prediction and correction methods, Factors affecting the maintenance and their evaluation.
Unit-IV
Rotary compressor system–various components and their functions. Classification of compressors. Design of compressor – data and analysis. Characteristics of the compressors. Selection of the drive and compressors. Development of the schematic layout of the compressor system.
Unit-V
Design of impeller, Types of impellers–centrifugal and axial. Design of a diffuser–Vane less and vaned diffuser. Types of casings, casing design, Performance characteristics of turbo compressors. Case studies
Topics to be taught by Industry Subject Expert :
Case studies related to design of compressors and pumps and application of various types of compressors and pumps in power generation plants

Suggested Reading:

1	S.M. Yahya, Turbines, Compressors and Fans, Tata McGraw Hill Publishing Co, 2010
2	Val.S. Lobanoff and Robert R. Ross, Centrifugal Pumps–Designs and Application, Jaico book publishing Co. 1992
3	Marc Borremans, Pumps and Compressors , Wiley-ASME Press Series, 2019
4	Maurice L. Adams, Rotating Machinery Research and Development Test Rigs, CRC Press, 2017
5	Hassan M. Badr, Wael H. Ahmed, Pumping Machinery Theory and Practice, Wiley, 2015

ME225	**HYDRAULIC MACHINERY**					
	(PROGRAMELECTIVE– V)					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60Marks	**CIE**		40Marks	

Course Objectives:	
On completion of this course, the student will be able to:	
1	understand laws of fluid mechanics and evaluate pressure, velocity and acceleration fields for various fluid flows related to hydraulic machines
2	Evaluate the performance parameters for hydraulic machinery.
3	Introduce the applications of momentum principles to hydraulic machines
4	To impart the knowledge on pumps and turbines
5	To make the students to have thorough knowledge on the selection of turbines and pumps for practical purposes

Course Outcomes:	
On completion of this course, the student will be able to do:	
CO-1	derive and apply general governing equations for various fluid flows for various turbomachines
CO-2	Understand different types of turbines and their applications and further analyze their working principles.
CO-3	Evaluate the performance characteristics of hydraulic turbines and pumps
CO-4	Distinguish between different classes of pumps, their construction features and further Analyze their performance.
CO-5	Explain the working principles of various hydraulic systems, and select a suitable hydraulic device for a particular application

Program Articulation Matrix

Course outcomes	**Program outcomes**				
	PO1	**PO2**	**PO3**	**PO4**	**PO5**
CO1	2	2	1	1	2
CO2	2	3	3	2	2
CO3	3	3	2	2	3
CO4	2	3	3	2	2
CO5	3	3	3	2	2

Unit-I

Introduction: Euler's turbomachinery equation, aerofoil and cascade theory, impulse and reaction principle, specific speed.

Hydraulic Turbines: Classification, Pelton, Francis, Kaplan, propeller and bulb turbines, velocity triangles, power and efficiency calculations, draft tube, cavitation, Thoma's cavitation factor, governing of impulse and reaction turbines.

Unit-II
Reaction turbine design: General procedure, general project layout, design of a Francis runner, design of the spiral casing and the distributor, draft tube role, CFD validation of the design, design fix.
Unit-III
Pelton turbine design: general procedure, project layout, injector design, bucket design, mechanical problems.
Unit-IV
Rotodynamic Pumps: Classifications, centrifugal, mixed and axial flow pumps, velocity triangles; Head, power and efficiency calculations, system losses and system head, impeller slip and slip factors, Hydraulic design of fans and compressors, internal and stage efficiency, stalling
Unit-V
Performance Characteristics of Rotodynamic Machines: Head, capacity and power measurement, performance characteristics, operating characteristics, model testing, similarity laws, Muschal or constant efficiency curves. Case studies
Topics to be taught by Industry Subject Expert:
Case studies related to design of hydraulic turbines application of various types of turbines, and case studies

Suggested Reading:

1	Lal, J., Hydraulic Machines, Metropolitan Book Co. Private Limited, 2003, 6th edition.
2	Gopal Krishnan & Prithviraj, A treatise on Turbomachines, Scitech Publications, 2002
3	Som and Biswas, Introduction to fluid Mechanics, Tata McGraw Hill, 2nd Edition
4	Mosonyi, E., Water Power Development, Vol. I and II, Nem Chand & Bros, 2009, 3rd edition.
	P.N. Modi& S.M. Seth, Hydraulics and fluid mechanics: including hydraulic machines, 18th edition, Standard Book House 2011.

OE 941 BM	**MEDICAL ASSISTIVE DEVICES**					
(OPEN ELECTIVE)						
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	To extend knowledge of the amputee, of lost and remaining functions affecting locomotion, and to collect information on the best possible medical treatment.
2	To improve fitting techniques and practices, including training, so that existing devices might be used with greater comfort and function.
3	To develop improved lower-extremity devices

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	Apply fundamental knowledge of engineering in rehabilitation
CO-2	Apply analytical skills to assess and evaluate the need of the end-user
CO-3	Develop self-learning initiatives and integrate learned knowledge for problem solving
CO-4	Understand the basics of robotics and apply their principles in developing prosthetics
CO-5	Apply the knowledge of computers in solving rehabilitation problems

Course outcome	**Program Outcome**					
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	2	1	3	2	1	1
CO-2	3	2	1	1	2	-
CO-3	2	2	2	3	2	1
CO-4	1	3	1	2	1	1
CO-5	1	1	2	3	2	3

Unit – I
Introduction to Rehabilitation Engineering, Measurement and analysis of human movement, Disability associated with aging in the workplace and their solutions, clinical practice of rehabilitation engineering.

Unit – II
Assistive Technology, Seating Biomechanics and systems. Wheeled Mobility: Categories of Wheelchairs. Wheelchair Structure and Component Design. Ergonomics of Wheel chair propulsion. Power Wheelchair Electrical Systems. Control. Personal Transportation. Auxiliary devices and systems.

Unit – III
Sensory augmentation and substitution: Visual system: Visual augmentation. Tactual vision substitution, Auditory vision substitution; Auditory system: Auditory augmentation. Cochlear implantation, Visual auditory substitution, Tactual auditory substitution, Tactual system: Tactual augmentation. Tactual substitution. Measurement tools and processes: fundamental principles, structure, function; performance and behavior. Subjective and objective measurement methods.

Unit – IV
Rehabilitation Robotics, Major Limb Prosthetic Devices, Orthotic Devices, Types of orthotics and prosthetics, Intelligent prosthetic Knee, Prosthetic Hand, Controlled orthotics and prosthetics FES system, Restoration of Hand function, Restoration of standing and walking, Myo-electric Hand.

Unit – V
Augmentative and Alternative communication technology, Computer applications in Rehabilitation Engineering, telecommunications, and Web Accessibility.

Suggested Reading:

1	Robinson C.J., *Rehabilitation Engineering*, CRC Press, 1995.
2	Ballabio E., et al., *Rehabilitation Technology*, IOS Press, 1993.
3	Rory A Cooper, Hisaichi Ohnabe, Douglas A. Hobson, *Series in medical physis and biomedical engineering: An introduction to rehabilitation engineering*, Taylor and Francis Group, London, 2007.
4	Joseph D. Bronzino *The biomedical engineering handbook -biomedical engineering fundamentals*, 3rdEd., CRC Press, Taylor & Francis Group, London, 2006.

OE 942 BM	**MEDICAL IMAGING TECHNIQUES**					
	(OPEN ELECTIVE)					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	To familiarize the students with various medical imaging modalities.
2	To make learners understand the principles, detectors and operating procedures of X-ray, CT, MRI, ultrasound, PET and SPECT.
3	To make the students learn the advantages, disadvantages and hazards of various medical imaging equipment.

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	Interpret the working principle and operating procedure and applications of X-ray equipment.
CO-2	Understand the image reconstruction techniques and applications of CT.
CO-3	Summarize the image acquisition and reconstruction techniques in MRI.
CO-4	Comprehend the working principle, modes and medical applications of ultrasound imaging.
CO-5	Examine the operation and applications of PET, SPECT and radio nuclide instrumentation.

Course outcome	**Program Outcome**					
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	2	1	3	2	1	1
CO-2	3	2	1	1	2	-
CO-3	2	2	2	3	2	1
CO-4	1	3	1	2	1	1
CO-5	1	1	2	3	2	3

Unit – I

X ray Imaging: Electromagnetic spectrum, Production of X-rays, X-ray tubes- Stationary and Rotating Anode types, Block diagram of an X-Ray Machine, Collimators and Grids, Timing and Exposure controls. X-Ray Image visualization-Films, Fluorescent screens, Image Intensifiers. Dental X-Ray machines, Portable and mobile X-Ray units, Mammographic X-Ray equipment, Digital Radiography and flat panel detectors.
Radiation safety, ALARA principle, Dose units and dose limits, Radiation dosimeters and detectors.

Unit – II

Computed Tomography: Basic principles, CT number scale, CT Generations. Major sub systems- Scanning system, processing unit, viewing unit, storage unit. Need and Principle of sectional imaging, 2D image reconstruction techniques - Iteration and Fourier methods. Applications of CT - Angio, Osteo, Dental, Perfusion (Body & Neuro), Virtual Endoscopy, Coronary Angiography.

Unit – III
Magnetic Resonance Imaging: Principles of NMR imaging systems, Image reconstruction techniques-Relaxation processes, imaging/ pulse sequences. Sub systems of an NMR imaging system, NMR detection system, types of coils, biological effects and advantages of NMR imaging. Functional MRI - The BOLD effect, intra and extra vascular field offsets, source of T2* effects, Creating BOLD contrast sequence optimization sources and dependences of physiological noise in fMRI.

Unit – IV
Ultrasound Imaging: - Principles of image formation -Imaging principles and instrumentation of A-mode, B-Mode, Gating Mode, Transmission mode and M-mode. Basics of multi-element linear array scanners, Digital scan conversion. Doppler Ultrasound and Colour Doppler imaging, Image artifacts, Biological effects, Ultrasound applications in diagnosis, therapy and surgery.

Unit – V
Nuclear Medicine–Radioisotopes in medical diagnosis, Basic instrumentation- Radiation detectors, Pulse height analyzer, Rectilinear scanner, Gamma camera. Emission Computed Tomography (ECT), Principle and instrumentation of Single Photon Emission Computed Tomography(SPECT) and Positron Emission Tomography (PET). Comparison of SPECT, PET and combined PET/ X-ray CT.

Suggested Reading:

1	Khandpur R.S., *Handbook of Biomedical Instrumentation*, Tata McGraw Hill, 2016.
2	S Webb, "*The Physics of Medical Imaging*", Adam Highler, Bristol Published by CRC Press, 1988.
3	A C Kak, "*Principle of Computed Tomography*", IEEE Press New York, 1988.
4	Hykes, Heorick, Starchman, *Ultrasound physics and Instrumentation* MOSBY year book, 2nd Ed. 1992.
5	Stewart C.Bushong, *Magnetic Resonance Imaging- physical and biological principles*, MOSBY, 2nd Ed., 1995.

OE 941 CE	**GREEN BUILDING TECHNOLOGY**					
	(OPEN ELECTIVE)					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	Exposure to the green building technologies and their significance.
2	Understand the judicial use of energy and its management.
3	Educate about the Sun-earth relationship and its effect on climate.
4	Enhance awareness of end-use energy requirements in the society.
5	Develop suitable technologies for energy management

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	Understand the fundamentals of energy use and energy processes in building.
CO-2	Identify the energy requirement and its management.
CO-3	Know the Sun-earth relationship vis-a-vis its effect on climate.
CO-4	Be acquainted with the end-use energy requirements.
CO-5	Be familiar with the audit procedures of energy

Course outcome	**Program Outcome**					
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	3	3	3	2	1	2
CO-2	3	2	3	2	1	1
CO-3	3	2	3	2	1	2
CO-4	3	2	3	2	1	2
CO-5	3	2	3	2	1	1

Unit – I

Overview of the significance of energy use and energy processes in building - Indoor activities and environmental control - Internal and external factors on energy use and the attributes of the factors - Characteristics of energy use and its management - Macro aspect of energy use in dwellings and its implications.

Unit – II

Indoor environmental requirement and management - Thermal comfort - Ventilation and air quality – Air-conditioning requirement - Visual perception - Illumination requirement - Auditory requirement.

Unit – III

Climate, solar radiation and their influences - Sun-earth relationship and the energy balance on the earth's surface - Climate, wind, solar radiation, and temperature - Sun shading and solar radiation on surfaces - Energy impact on the shape and orientation of buildings.

Unit – IV
End-use, energy utilization and requirements - Lighting and day lighting - End-use energy requirements - Status of energy use in buildings Estimation of energy use in a building. Heat gain and thermal performance of building envelope - Steady and non-steady heat transfer through the glazed window and the wall - Standards for thermal performance of building envelope - Evaluation of the overall thermal transfer.

Unit – V
Nuclear Medicine–Radioisotopes in medical diagnosis, Basic instrumentation- Radiation Energy management options - Energy audit and energy targeting - Technological options for energy management.

Suggested Reading:

1	Bryant Edwards (2005): Natural Hazards, Cambridge University Press, U.K.
2	Carter, W. Nick, (1991): Disaster Management, Asian Development Bank, Manila.
3	Sahni, Pardeep et.al. (eds.) (2002), Disaster Mitigation Experiences and Reflections, Prentice Hall of India, New Delhi.
4	Bryant Edwards (2005): Natural Hazards, Cambridge University Press, U.K.

OE 942 CE	**COST MANAGEMENT OF ENGINEERING PROJECTS**					
	(OPEN ELECTIVE)					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	Introduce the concepts of cost management
2	Fundamentals of cost overruns
3	Introduce the concepts of Quantitative techniques for cost management Linear Programming, PERT/CPM.

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	Understanding of strategic cost management process, control of cost and decision making based on the cost of the project.
CO-2	Ability to appreciative detailed engineering activities of the project and execution of projects
CO-3	Preparation of project report and network diagram
CO-4	Able to plan Cost Behavior , Profit Planning , Enterprise Resource Planning, Total Quality Management.
CO-5	Applications of various quantitative techniques for cost management

Course outcome	**Program Outcome**					
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	2	1	3	2	1	1
CO-2	3	2	1	1	2	-
CO-3	2	2	2	3	2	1
CO-4	1	3	1	2	1	1
CO-5	1	1	2	3	2	3

Unit – I
Introduction and Overview of the Strategic Cost Management Process-Cost concepts in decision-making; relevant cost, Differential cost, Incremental cost and Opportunity cost. Objectives of a Costing System- Inventory valuation- Creation of a Database for operational control; Provision of data for Decision-Making.

Unit – II
Project: meaning, Different types, why to manage, cost overruns centres, various stages of project execution: conception to commissioning- Project execution as conglomeration of technical and non-technical activities- Detailed Engineering activities.

Unit – III
Pre project execution main clearances and documents Project team: Role of each member. Importance Project site: Data required with significance. Project contracts. Types and contents. Project execution Project cost control. Bar charts and Network diagram. Project commissioning: mechanical and process.

Unit – IV
Cost Behavior and Profit Planning Marginal Costing; Distinction between Marginal Costing and Absorption Costing; Break-even Analysis, Cost-Volume-Profit Analysis. Various decision-making problems- Standard Costing and Variance Analysis. Pricing strategies: Pareto Analysis. Target costing, Life Cycle Costing. Costing of service sector- Just-in-time approach, Material Requirement Planning, Enterprise Resource Planning, Total Quality Management and Theory of constraints- Activity-Based Cost Management, Bench Marking; Balanced Score Card and Value-Chain Analysis. Budgetary Control; Flexible Budgets- Performance budgets- Zero-based budgets. Measurement of Divisional profitability pricing decisions including transfer pricing.

Unit – V
Quantitative techniques for cost management, Linear Programming, PERT/CPM,- Transportation problems, Assignment problems, Simulation, Learning Curve Theory.

Suggested Reading:

1	Cost Accounting A Managerial Emphasis, Prentice Hall of India, New Delhi
2	Charles T. Horngren and George Foster, Advanced Management Accounting
3	Robert S Kaplan Anthony A. Alkinson, Management & Cost Accounting
4	Ashish K. Bhattacharya, Principles & Practices of Cost Accounting A. H. Wheeler publisher
5	N.D. Vohra, Quantitative Techniques in Management, Tata McGraw Hill Book Co. Ltd.

OE 941 CS	**BUSINESS ANALYTICS**					
(OPEN ELECTIVE)						
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	Understanding the basic concepts of business analytics and applications
2	Study various business analytics methods including predictive, prescriptive and prescriptive analytics
3	Prepare the students to model business data using various data mining, decision making methods

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	To understand the basic concepts of business analytics
CO-2	Identify the application of business analytics and use tools to analyze business data
CO-3	Become familiar with various metrics, measures used in business analytics
CO-4	Illustrate various descriptive, predictive and prescriptive methods and techniques
CO-5	Model the business data using various business analytical methods and techniques

Course outcome	**Program Outcome**					
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	2	1	3	2	1	1
CO-2	3	2	1	1	2	-
CO-3	2	2	2	3	2	1
CO-4	1	3	1	2	1	1
CO-5	1	1	2	3	2	3

Unit – I

Introduction to Business Analytics: Introduction to Business Analytics, need and science of data driven (DD) decision making, Descriptive, predictive, prescriptive analytics and techniques, Big data analytics, Web and Social media analytics, Machine Learning algorithms, framework for decision making, challenges in DD decision making and future.

Unit – II

Descriptive Analytics: Introduction, data types and scales, types of measurement scales, population and samples, measures of central tendency, percentile, decile and quadrille, measures of variation, measures of shape-skewness, data visualization.

Unit – III

Forecasting Techniques: Introduction, time-series data and components, forecasting accuracy, moving average method, single exponential smoothing, Holt's method, Holt-Winter model, Croston's forecasting method, regression model for forecasting, Auto regression models, auto-regressive moving process, ARIMA, Theil's coefficient

Unit – IV
Decision Trees: CHAID, Classification and Regression tree, splitting criteria, Ensemble and method and random forest. **Clustering**: Distance and similarity measures used in clustering, Clustering algorithms, K-Means and Hierarchical algorithms, **Prescriptive Analytics**- Linear Programming (LP) and LP model building.

Unit – V
Six Sigma: Introduction, introduction, origin, 3-Sigma Vs Six-Sigma process, cost of poor quality, sigma score, industry applications, six sigma measures, DPMO, yield, sigma score, DMAIC methodology, Six Sigma toolbox.

Suggested Reading:

1	U Dinesh Kumar, "Data Analytics", Wiley Publications, 1st Edition, 2017
2	Marc J. Schniederjans, Dara G. Schniederjans, Christopher M. Starkey, "Business analytics Principles, Concepts, and Applications with SAS", Associate Publishers, 2015
3	S. Christian Albright, Wayne L. Winston, "Business Analytics - Data Analysis and Decision Making", 5th Edition, Cengage, 2015

Web Resources:

1	https://onlinecourses.nptel.ac.in/noc18-mg11/preview
2	https://nptel.ac.in/courses/110105089/

OE 941 EC	**ELEMENTS OF EMBEDDED SYSTEMS**					
(OPEN ELECTIVE)						
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	Understanding various Embedded Design strategies
2	Designing Micro controller based Embedded Systems
3	Designing FPGA Based Embedded Systems

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	Understand Embedded Design Strategies and architecture of Arduino Board
CO-2	Program using various onboard components of Arduino
CO-3	Design real time interfacing with Arduino
CO-4	Understand Design Flow of FPGA, programming FPGA using Verilog HDL
CO-5	Implement combinational and sequential circuits using verilog HDL

Course outcome	**Program Outcome**					
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	2	1	3	2	1	1
CO-2	3	2	1	1	2	-
CO-3	2	2	2	3	2	1
CO-4	1	3	1	2	1	1
CO-5	1	1	2	3	2	3

Unit – I

Embedded Systems Design Strategies: Micro Controller, DSP, FPGA, Introduction to Arduino (Micro controller Board), Components of Arduino, Architecture and Pin Configuration of ATMega328, Ports of ATMega328.

Unit – II

Interfacing: Interfacing Switches, LEDs, Analog to Digital Converter, Digital to Analog Converter, Interfacing and Programming I2C, SPI

Unit – III

Real Time Programming: Interfacing Key Pad, 7-segment display, LCD, Interfacing Sensors, Interfacing Stepper Motor**,** USB programming

Unit – IV

FPGA Based Embedded Design: FPGA Design flow, Introduction to Verilog HDL**,** Basic building blocks, Data types of Verolog HDL, Behavioral Modelling, Data Flow Modelling, Structural Modelling, Hierarchal Structural Modelling, Case Studies on Verilog HDL descriptions of Basic Circuits

Unit – V
Modelling of Circuits: Verilog HDL Implementation of Combinational MSI Circuits, Verilog HDL Implementation of Sequential MSI Circuits, Finite Sate Machine Design, Tasks and Functions, Introduction to Test Benches

Suggested Reading:

1	Ming-Bo Lin, Digital System Designs and Practices Using Verilog HDL and FPGAs, Wiley India, 2008
2	Samir Palnitkar, Verilog HDL: A Guide to Digital Design and Synthesis, Pearson Education, 2005
3	Simon Monk, Programming Arduino: Getting Started with sketches, Mc.Hill, 2016

Web Resources:

1	www.arduino.cc
2	www.learn.sparkfun.com/tutorials/arduino

OE 941 EE	**WASTE TO ENERGY**					
	(OPEN ELECTIVE)					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	To know the various forms of waste
2	To understand the processes of Biomass Pyrolysis.
3	To learn the technique of Biomass Combustion.

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	Understand the concept of conservation of waste
CO-2	Identify the different forms of wastage.
CO-3	Chose the best way for conservation to produce energy from waste.
CO-4	Explore the ways and means of combustion of biomass.
CO-5	Develop a healthy environment for the mankind.

Course outcome	**Program Outcome**					
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	3	-	3	2	3	1
CO-2	3	-	3	2	3	1
CO-3	3	-	3	2	3	1
CO-4	3	-	3	2	3	1
CO-5	3	-	3	2	3	1

Unit – I
Introduction to Energy from Waste: Classification of waste as fuel – Agro based, Forest residue, Industrial waste - MSW – Conversion devices – Incinerators, gasifiers, digestors.

Unit – II
Biomass Pyrolysis: Pyrolysis – Types, slow fast – Manufacture of charcoal – Methods Yields and application – Manufacture of pyrolytic oils and gases, yields and applications.

Unit – III
Biomass Gasification: Gasifiers – Fixed bed system – Downdraft and updraft gasifiers Fluidized bed gasifiers – Design, construction and operation – Gasifier burner arrangement for thermal heating – Gasifier engine arrangement and electrical power – Equilibrium and kinetic consideration in gasifier operation.

Unit – IV
Biomass Combustion: Biomass stoves – Improved chullahs, types, some exotic designs, Fixed bed combustors, Types, inclined grate combustors, Fluidized bed combustors, Design, construction and operation - Operation of all the above biomass combustors.

Unit – V
Biogas: Properties of biogas (Calorific value and composition) - Biogas plant technology and status - Bio energy system - Design and constructional features - Biomass resources and their classification - Biomass conversion processes - Thermo chemical conversion - Direct combustion - biomass gasification - pyrolysis and liquefaction - biochemical conversion anaerobic digestion - Types of biogas Plants – Applications - Alcohol production from biomass Bio diesel production - Urban waste to energy conversion - Biomass energy programme in India.

Suggested Reading:

1	n Conventional Energy, Desai, Ashok V., Wiley Eastern Ltd., 1990.
2	ogas Technology - A Practical Hand Book - Khandelwal, K. C. and Mahdi, S. S., Vol. I & II, Tata McGraw Hill Publishing Co. Ltd., 1983.
3	od, Feed and Fuel from Biomass, Challal, D. S., IBH Publishing Co. Pvt. Ltd., 1991.
4	omass Conversion and Technology, C. Y. WereKo-Brobby and E. B. Hagan, John Wiley & Sons, 1996.

OE 942 EE	**POWER PLANT CONTROL AND INSTRUMENTATION**					
	(OPEN ELECTIVE)					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	The operation of different types of power plants.
2	The basic working principle of instruments for measurement of electrical and non-electrical quantities like Temperature Pressure flow level measurements.
3	The instrumentation and protection systems applied in thermal power plant.
4	The control techniques employed for the operation of modern power generation plant

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	Explain the different methods of power generation. Along with Piping and Instrumentation diagram of boiler.
CO-2	Select various measurements involved in power generation for measuring electrical and non-electrical parameters.
CO-3	Identify the different types of analyzers used for scrutinizing boiler steam and water.
CO-4	Model different types of controls and control loops in boilers.
CO-5	Illustrate the methods of monitoring and control of different parameters like speed, vibration of turbines

Course outcome	**Program Outcome**					
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	3	1	-	-	-	2
CO-2	3	1	-	-	-	2
CO-3	3	1	-	-	-	2
CO-4	3	1	-	-	-	2
CO-5	3	1	-	-	-	2

Unit – I
Brief survey of methods of power generation, hydro, thermal, nuclear, solar and wind power, importance of instrumentation in power generation, thermal power plants, block diagram, details of boiler processes, Piping and Instrumentation diagram of boiler, cogeneration.

Unit – II
Electrical measurements, current, voltage, power, frequency, power factor etc, non-electrical parameters, flow of feed water, fuel, air and steam with correction factor for temperature, steam pressure and steam temperature, drum level measurement, radiation detector, smoke density measurement, dust monitor.

Unit – III
Flue gas oxygen analyzer: Analysis of impurities in feed water and steam, dissolved oxygen analyzer. Chromatography, pH meter, fuel analyzer, pollution monitoring instruments.

Unit – IV
Combustion control, air / fuel ratio control, furnace draft control, drum level control, main steam and reheat steam temperature control, super heater control, air temperature, distributed control system in power plants, interlocks in boiler operation.

Unit – V
Speed, vibration, shell temperature monitoring and control, steam pressure control, lubricant oil temperature control, cooling system.

Suggested Reading:

1	Sam G. Dukelow, The Control of Boilers, Instrument Society of America, 2nd Edition, 2010.
2	P.K. Nag, „Power Plant Engineering", Tata McGraw-Hill, 1st Edition, 2001.
3	S.M. Elonka and A.L. Kohal, "Standard Boiler Operations", Tata McGraw-Hill, 1st Edition, 1994.
4	R K Jain, "Mechanical and Industrial Measurements", Khanna Publishers, 1st Edition, 1995.
5	E Al Wakil, "Power Plant Engineering", Tata McGraw-Hill, 1st Edition, 1984.

OE 942 ME	**COMPOSITE MATERIALS**					
	(OPEN ELECTIVE)					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	*Study the concepts of composite construction.*
2	*Learn analysis and designs of composite beams, floors, columns and trusses as per the recommendations of IS codes of practice.*
3	*Apply the concepts for design of multi-storey composite buildings.*
4	*Scope of analysis is restricted to skeletal structures subjected to prescribed dynamic loads.*

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	*Understand the fundamentals of composite construction, and analysis and designs of composite beams.*
CO-2	*Analyse and design the composite floors*
CO-3	*Select suitable materials for composite columns,*
CO-4	*Analyse composite trusses and understand connection details.*
CO-5	*Analyse and design the multi-storey composite buildings*

Course outcome	**Program Outcome**					
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	2	1	3	2	1	1
CO-2	3	2	1	1	2	-
CO-3	2	2	2	3	2	1
CO-4	1	3	1	2	1	1
CO-5	1	1	2	3	2	3

Unit – I

Introduction of composite constructions:Benefits of composite construction - Introduction to IS - BS and Euro codal provisions.
Composite beams:Elastic behaviour of composite beams - No and full interaction cases - Shear connectors - Ultimate load behaviour - Serviceability limits - Effective breadth of flange - Interaction between shear and moment - Basic design consideration and design of composite beams.

Unit – II

Composite floors:Structural elements - Profiled sheet decking - Bending resistance - Shear resistance - Serviceability criterion - Analysis for internal forces and moments - Design of composite floors.

Unit – III
Composite columns: Materials - Concrete filled circular tubular sections - Non-dimensional slenderness - Local buckling of steel sections - Effective elastic flexural stiffness - Resistance of members to axial compressions - Composite column design - Fire resistance.

Unit – IV
Composite trusses: Design of truss - Configuration - Truss members - Analysis and design of composite trusses and connection details.

Unit – V
Design of multi-storey composite buildings: Design basis - Load calculations - Design of composite slabs with profile decks - Composite beam design - Design for compression members - Vertical cross bracings - Design of foundation.

Suggested Reading:

1	R.P. Johnson, "Composite Structures of Steel and Concrete - Beams, Slabs, Columns and Frames in Buildings", Blackwell Publishing, Malden, USA, 2004.
2	"INSDAG Teaching Resources for Structural Steel Design", Vol-2, Institute for Steel Development and Growth Publishers, Calcutta, India.
3	"INSDAG Handbook on Composite Construction – Multi-Storey Buildings", Institute for Steel Development and Growth Publishers, Calcutta, India.
4	"INSDAG Design of Composite Truss for Building", Institute for Steel Development and Growth Publishers, Calcutta, India.
5	"INSDAG Handbook on Composite Construction – Bridges and Flyovers", Institute for Steel Development and Growth Publishers, Calcutta, India.
6	IS: 11384-1985, "Code of Practice for Composite Construction in Structural Steel and Concrete", Bureau of Indian Standards, New Delhi, 1985.

OE 941 ME	**OPERATION RESEARCH**					
(OPEN ELECTIVE)						
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	To understand the dynamic programming to solve problems of discrete and continuous variables
2	To apply the concept of non-linear programming and carry out sensitivity analysis
3	To understand deterministic and probabilistic inventory control models.

Course Outcomes:	
After the completion of this course, the students shall be able to:	
CO-1	To understand the basics of OR, including mathematical modeling, feasible solutions and optimization.
CO-2	Able to carry out sensitivity analysis.
CO-3	Apply PERT/CPM in project management.
CO-4	Select appropriate inventory control model.
CO-5	Able to apply dynamic programming and understand the concept of non-linear programming.

Course Outcome	**Program Outcome**					
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	1	1	3	2	1	2
CO-2	3	1	2	3	2	-
CO-3	1	3	3	1	2	2
CO-4	3	2	1	3	1	1
CO-5	2	1	3	2	2	2

Unit – I
Development, Different Phases, Characteristics, Operations Research models and applications. Linear Programming Problem: Introduction, Basic Assumptions, Formulation, graphical method, simplex method: Big M and Two Phase method.

Unit – II
DUALITY: Duality theory, primal-dual relationships, Economic interpretation, Dual simplex method, Post optimal or sensitivity analysis.

Unit – III
Project Management: Introduction to PERT and CPM, critical Path calculation, float calculation and its importance. Cost reduction by Crashing of activity. **Inventory models** – Economic order quantity models – Quantity discount models – Stochastic inventory models – Multi product models – Inventory control models in practice.

Unit – IV

Sequencing Models: Introduction, General assumptions, processing n jobs through 2 machines, processing 'n' jobs through m machines. **Game Theory**: Introduction, Characteristics of Game Theory, Dominance theory, Mixed strategies (2 x 2, m x 2), Algebraic and graphical methods. **Nonlinear programming problem:** - Kuhn-Tucker conditions.

Unit – V
Queuing models - Queuing systems and structures – Notation parameter – Single server and multi server models – Poisson arrivals – Exponential service times – with finite population – Infinite population. Dynamic Programming: Characteristics, principle of optimality, deterministic problems.

Suggested Reading:

1	H.A. Taha, Operations Research, An Introduction, PHI,2008
2	H.M. Wagner, Principles of Operations Research, PHI, Delhi,2010
3	J.C. Pant, Introduction to Optimization: Operations Research, Jain Brothers,Delhi, 2008.
4	Frederick S. Hillier, Gerald J. Lieberman, Operations Research, 10thEdition, McGraw Hill Pub. 2017.
5	Panner selvam, Operations Research: Prentice Hall of India, 2010.
6	Ronald L. Rardin, Optimization in Operations Research, First Indian Reprint, Pearson Education Asia. 2002,

OE943 ME	**INDUSTRIAL SAFETY**					
(OPEN ELECTIVE)						
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	Causes for industrial accidents and preventive steps to be taken.
2	Fundamental concepts of Maintenance Engineering.
3	About wear and corrosion along with preventive steps to be taken
4	The basic concepts and importance of fault tracing.
5	The steps involved in carrying out periodic and preventive maintenance of various equipments used in industry

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	Identify the causes for industrial accidents and suggest preventive measures.
CO-2	Identify the basic tools and requirements of different maintenance procedures.
CO-3	Apply different techniques to reduce and prevent Wear and corrosion in Industry.
CO-4	Identify different types of faults present in various equipments like machine tools, IC Engines, boilers etc.
CO-5	Apply periodic and preventive maintenance techniques as required for industrial equipments like motors, pumps and air compressors and machine tools etc

Course outcome	**Program Outcome**					
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	2	1	3	2	1	1
CO-2	3	2	1	1	2	-
CO-3	2	2	2	3	2	1
CO-4	1	3	1	2	1	1
CO-5	1	1	2	3	2	3

Unit – I

Industrial safety: Accident, causes, types, results and control, mechanical and electrical hazards, types, causes and preventive steps/procedure, describe salient points of factories act 1948 for health and safety, wash rooms, drinking water layouts, light, cleanliness, fire, guarding, pressure vessels, etc, Safety color codes, Fire prevention and firefighting, equipment and methods.

Unit – II

Fundamentals of Maintenance Engineering: Definition and aim of maintenance engineering, Primary and secondary functions and responsibility of maintenance department, Types of maintenance, Types and applications of tools used for maintenance, Maintenance cost & its relation with replacement economy, Service life of equipment.

Unit – III
Wear and Corrosion and their Prevention: Wear- types, causes, effects, wear reduction methods, lubricants-types and applications, Lubrication methods, general sketch, working and applications of Screw down grease cup, Pressure grease gun, Splash lubrication, Gravity lubrication, Wick feed lubrication, Side feed lubrication, Ring lubrication, Definition of corrosion, principle and factors affecting the corrosion, Types of corrosion, corrosion prevention methods.

Unit – IV
Fault Tracing: Fault tracing-concept and importance, decision tree concept, need and applications, sequence of fault finding activities, show as decision tree, draw decision tree for problems in machine tools, hydraulic, pneumatic, automotive, thermal and electrical equipment's like, any one machine tool, Pump, Air compressor, Internal combustion engine, Boiler, Electrical motors, Types of faults in machine tools and their general causes.

Unit – V
Periodic and Preventive Maintenance: Periodic inspection-concept and need, degreasing, cleaning and repairing schemes, overhauling of mechanical components, overhauling of electrical motor, common troubles and remedies of electric motor, repair complexities and its use, definition, need, steps and advantages of preventive maintenance. Steps/procedure for periodic and preventive maintenance of Machine tools, Pumps, Air compressors, Diesel generating (DG) sets, Program and schedule of preventive maintenance of mechanical and electrical equipment, advantages of preventive maintenance. Repair cycle concept and importance.

Suggested Reading:

1	H. P. Garg, "Maintenance Engineering", S. Chand and Company
2	Audels, "Pump-hydraulic Compressors", Mcgraw Hill Publication
3	Higgins & Morrow, "Maintenance Engineering Handbook", Da Information Services.
4	Winterkorn, Hans, "Foundation Engineering Handbook", Chapman & Hall London

OE 941 LA	**INTELLECTUAL PROPERTY RIGHTS**					
(OPEN ELECTIVE)						
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	Acquaint the students with basics of intellectual property rights with special reference to Indian Laws and its practices.
2	Compare and contrast the different forms of intellectual property protection in terms of their key differences and similarities.
3	Provide an overview of the statutory, procedural, and case law underlining these processes and their interplay with litigation.

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	Understand the concept of intellectual property rights.
CO-2	Develop proficiency in trademarks and acquisition of trade mark rights.
CO-3	Understand the skill of acquiring the copy rights, ownership rights and transfer.
CO-4	Able to protect trade secrets, liability for misappropriations of trade secrets.
CO-5	Apply the patents and demonstration of case studies.

Course outcome	**Program Outcome**					
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	2	1	3	2	1	1
CO-2	3	2	1	1	2	-
CO-3	2	2	2	3	2	1
CO-4	1	3	1	2	1	1
CO-5	1	1	2	3	2	3

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

Unit – II
Trade Marks: Purpose and function of trademarks, acquisition of trade mark rights, protectable matter, selecting, and evaluating trade mark, trade mark registration processes.

Unit – III
Law of copy rights: Fundamental of copy right law, originality of material, rights of reproduction, rights to perform the work publicly, copy right ownership issues, copy right registration, notice of copy right, international copy right law. Law of patents: Foundation of patent law, patent searching process, ownership rights and transfer**.**

Unit – IV
Trade Secrets: Trade secrete law, determination of trade secrete status, liability for misappropriations of trade secrets, protection for submission, trade secrete litigation. Unfair competition: Misappropriation right of publicity, false advertising.

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

Suggested Reading:

1	Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd, 2007.
2	"Mayall, "Industrial Design", McGraw Hill,1992
3	"Niebel, "Product Design", McGraw Hill,1974.
4	"Asimov, "Introduction to Design", Prentice Hall,1962.
5	"Robert P. Merges, Peter S. Menell, Mark A. Lemley, "Intellectual Property in New Technological Age",2016.
6	T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand,2008

ME252	**COMPUTATIONAL FLUID DYNAMICS LABORATORY (Lab-II)**					
Pre-requisites			**L**	**T**	**P**	**C**
			-	-	2	1
Evaluation	**SEE**	-	**CIE**		50 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	To provide students with the necessary skills to use commercial CFD packages
2	To carry out research in the area of Computational Fluid Dynamics.
3	To solve a variety of flow situations and heat transfer tutorials.

Course Outcomes:	
On completion of this course, the student will be able to:	
CO-1	Ability to define the problem domain, boundary conditions and perform simulations
CO-2	Critically evaluate and interpret the results
CO-3	Ability to perform different types of analysis
CO-4	Analyse the results and draw graphs, plots, vectors
CO-5	Prepare a well-organized report

Program Articulation Matrix

Course outcomes	**Program outcomes**				
	PO1	**PO2**	**PO3**	**PO4**	**PO5**
CO1	3	1	3	2	3
CO2	3	1	3	3	3
CO3	3	1	3	3	3
CO4	3	3	3	2	3
CO5	3	3	3	-	3

List of Experiments:

1. Introduction to CFD – Pre Processor, Solver, Post Processor
2. Ansys Work bench – Modelling tools
3. Ansys Work Bench – Grid Generation
4. Ansys CFX pre – Properties of fluids, Boundary Conditions
5. Ansys Solver, Post processor
6. Exercise 1 : Flow through a Nozzle – Modeling, Grid generation
7. Exercise 1 : Flow through a Nozzle – Pre, Solver, Post Processor
8. Exercise 2: Flow past a cylinder – Modeling, Grid generation
9. Exercise 2: Flow past a cylinder – Pre, Solver, Post Processor
10. Exercise 3 : Static Mixer – Modeling, Grid generation
11. Exercise 3 : Static Mixer – Pre, Solver, Post Processor
12. Exercise 4 : Flow Mixing in a pipe bend – Modeling, Grid generation
13. Exercise 4 : Flow Mixing in a pipe bend - Pre, Solver, Post Processor

ME 253	**COMPUTATION LAB FOR TM (Lab-III)**					
Pre-requisites			**L**	**T**	**P**	**C**
			-	-	2	1
Evaluation	**SEE**	-	**CIE**		50 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	Understanding the MATLAB environment
2	To introduce to the software MATLAB for numerical computations
3	To do simple calculations using MATLAB
4	Carry out simple numerical computations and analyses using MATLAB

Course Outcomes:	
On completion of this course, the student will be able to:	
CO-1	Ability to perform simulations and understand the phenomenon related to Thermal Engineering
CO-2	Able to do calculations using MATLAB
CO-3	Carry out numerical computations and analyse using MATLAB
CO-4	Critically evaluate and interpret the results
CO-5	Prepare a well-organized record

Program Articulation Matrix

Course outcomes	**Program outcomes**				
	PO1	**PO2**	**PO3**	**PO4**	**PO5**
CO1	3	3	3	2	2
CO2	3	3	3	2	2
CO3	3	3	3	3	2
CO4	3	3	3	3	2
CO5	3	3	3	3	2

LISTOFEXPERIMENTS

1. Evaluate the mathematical expressions in Matlab
2. Write scripts to make single-index arrays
3. Basic syntax and command-line exercises, Basic array exercises, Relational and logical operations
4. Control of flow: if-blocks , Loop constructs: for and while
5. Problems on generating various kinds of 2D & 3D Plots
6. Solving ordinary differential equations
7. Solving algebraic equations
8. Applications of Curve fitting and interpolation
9. Usage of Data Analysis and statistics
10. Modeling of problems related to turbomachinery

MC070	**MINI PROJECT**					
Pre-requisites	-		**L**	**T**	**P**	**C**
			-	-	4	2
Evaluation	**SEE**	-	**CIE**	50 Marks		

Course Objectives:	
On completion of this course, the student will be able to:	
1	Understand the purpose of doing mini project
2	Learn the resources available at the college and outside for pursuing project
3	Importance of literature review
4	Learn to select appropriate software and procedure
5	Learn to document results and arrive at required conclusions

Course Outcomes:	
On completion of this course, the student will be able to:	
CO-1	Identify engineering problems reviewing available literature
CO-2	Study different techniques used to analyze complex systems.
CO-3	Use related techniques and software's for solving the problem
CO-4	Interpret the results and arrive at the relevant conclusions.
CO-5	Document the findings as a technical report with proper references

Program Articulation Matrix

Course outcome	**Program outcome**				
	PO1	**PO2**	**PO3**	**PO4**	**PO5**
CO1	2	2	3	2	1
CO2	2	2	3	3	1
CO3	2	2	3	3	1
CO4	2	2	3	3	1
CO 5	2		3	3	1

Guidelines

1. Guide allocation will be done at the beginning of the semester. Identification of will be done with Guides consultation

2. Mini project presentation should be done along with the report on identification of topic for the work and the methodology adopted involving scientific research, collection and analysis of data, determining solutions highlighting individuals' contribution.

3. Evaluation of Mini project will be done by the Departmental Committee. Half of the marks are awarded by the Guide and the remaining half of the marks will be awarded by Departmental Committee.

SEMESTER-III

AC030 ME	**RESEARCH METHODOLOGY IN MECHANICAL ENGINEERING**					
AUDIT COURSE - I						
Pre-requisites			**L**	**T**	**P**	**C**
			2	-		0
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives :	
1	Learn to focus on research related activities.
2	Learn methods to devise and develop the various research designs
3	Learn basic principles of data collection and analysis techniques
4	Learn the style and format of writing a report for technical papers

Course Outcomes :After completion of the course student will be able to	
CO-1	Motivate the orientation towards research related activities
CO-2	Formulate the research problem, analyze research related information
CO-3	Identify various sources for literature review and design an experimentation set-up
CO-4	Apply the basic principles of data collection and analysis techniques
CO-5	Improve the style and format of writing a report for technical / Journal articles

UNIT – I

Research Methodology: Objectives and Motivation of Research, Types of Research, Research Approaches, Significance of Research, Research Methods verses Methodology, Research and Scientific Method, Important of Research Methodology, Research Process, Criteria of Good Research, Problems Encountered by Researchers in India, Benefits to the society in general.

Defining the Research Problem: Definition of Research Problem, Problem Formulation, Necessity of Defining the Problem, Technique involved in Defining a Problem

UNIT – II

Literature Survey: Importance of Literature Survey, Sources of Information, Assessment of Quality of Journals and Articles, Information through Internet. **Literature Review**: Need of Review, Guidelines for Review, Record of Research Review.

UNIT – III

Research Design: Meaning of Research Design, Need of Research Design, Feature of a Good Design Important Concepts Related to Research Design, Different Research Designs, Basic Principles of Experimental Design, Developing a Research Plan, Design of Experimental Set-up, Use of Standards and Codes.

UNIT – IV
Data Collection: Collection of primary data, Secondary data, Data organization, Methods of data grouping, Diagrammatic representation of data, Graphic representation of data. Sample Design, Need for sampling, some important sampling definitions, Estimation of population, Role of Statistics for Data Analysis, Parametric V/s Non Parametric methods, Descriptive Statistics, Measures of central tendency and Dispersion, Hypothesis testing, Use of Statistical software. **Data Analysis:** Deterministic and random data, Uncertainty analysis, Tests for significance: Chi-square, student's t-test, Regression modeling, Direct and Interaction effects, ANOVA, F-test, Time Series analysis, Autocorrelation and Autoregressive modeling

UNIT –V
Research Report Writing: Format of the Research report, Synopsis, Dissertation, Thesis its Differentiation, References/Bibliography/Webliography, Technical paper writing/Journal report writing, making presentation, Use of visual aids. **Research Proposal Preparation**: Writing a Research Proposal and Research Report, Writing Research Grant Proposal.

Suggested Reading:

1	C.R Kothari, Research Methodology, Methods & Technique; Revised Edition, New Age International Publishers, 2004
2	R. Ganesan, Research Methodology for Engineers, 1st Edition, MJP Publishers, 2011.
3	Ratan Khananabis and Suvasis Saha, Research Methodology, 1st Edition, Universities Press, Hyderabad, 2015
4	Y.P. Agarwal, Statistical Methods: Concepts, Application and Computation, 1st Edition, Sterling Publs., Pvt., Ltd., New Delhi, 2004
5	Vijay Upagade and Aravind Shende, Research Methodology, 1st Edition, S. Chand & Company Ltd., New Delhi, 2009
6	G. Nageswara Rao, Research Methodology and Quantitative methods, 2nd Edition, BS Publications, Hyderabad, 2012.

AC 031	**ENGLISH FOR RESEARCH PAPER WRITING**					
(AUDIT COURSE - II)						
Pre-requisites			**L**	**T**	**P**	**C**
			2	-		0
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	*Understand that how to improve your writing skills and level of readability*
2	*Understand the nuances of language and vocabulary in writing a Research Paper.*
3	*Develop the content, structure, format of writing a research paper and produce original research papers without plagiarism*

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	*Interpret the nuances of research paper writing.*
CO-2	*Differentiate the research paper format and citation of sources.*
CO-3	*To review the research papers and articles in a scientific manner.*
CO-4	*Avoid plagiarism and be able to develop their writing skills in presenting the research work.*
CO-5	*Create a research paper and acquire the knowledge of how and where to publish their original research papers*

Unit – I

Academic Writing: Meaning & Definition of a research paper– Purpose of a research paper – Scope – Benefits, Limitations – outcomes.

Unit – II

Research Paper Format: Title – Abstract – Introduction – Discussion – Findings, Conclusion – Style of Indentation – Font size/Font types – Indexing – Citation of sources.

Unit – III

Research Methodology: Methods (Qualitative – Quantitative) Review of Literature. Criticizing, Paraphrasing & Plagiarism.

Unit – IV

Process of Writing a research paper: Choosing a topic - Thesis Statement – Outline – Organizing notes - Language of Research – Word order, Paragraphs – Writing first draft –Revising/Editing - The final draft and proof reading.

Unit – V

Research Paper Publication: Reputed Journals – National/International – ISSN No, No. of volumes, Scopus Index/UGC Journals – Free publications - Paid Journal publications – Advantages/Benefits

Presentation Skills: Developing Persuasive Presentations, Structure of Presentation, Presentation Slides, Presentation Delivery, role of the audience, what to search and cite, how to establish credibility.

Suggested Reading:

1	C. R Kothari, Gaurav, Garg, "*Research Methodology Methods and Techniques*", 4/e, New Age International Publishers.
2	Day R, "*How to Write and Publish a Scientific Paper*", Cambridge University Press, 2006
3	"*MLA Hand book for writers of Research Papers*", 7/e, East West Press Pvt. Ltd, New Delhi
4	Lauri Rozakis, Schaum's, "*Quick Guide to Writing Great Research Papers*", Tata McGraw Hills Pvt. Ltd, New Delhi.

AC 032	DISASTER MITIGATION AND MANAGEMENT					
	(AUDIT COURSE - II)					
Pre-requisites			**L**	**T**	**P**	**C**
			2	-		0
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	*Introduction of various types of disasters and its effect on structures.*
2	*Learning of quality assurance and damage assessment of structures*
3	*Educate different types of repair, strengthening, rehabilitation and retrofitting techniques.*
4	*Awareness about flood characteristics and flood forecasting systems*
5	*Description of Flood mitigation, adjustment, and regulation*

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	*Understand the fundamentals of disaster and seismic performance of buildings*
CO-2	*Able to assess various damages in structures and give assurance of quality of concrete*
CO-3	*Decide the appropriate repair, strengthening, rehabilitation and technique required for a case study of building.*
CO-4	*Applications of flood routing, flood forecasting and space time characteristics of rainfall.*
CO-5	*Advanced understanding of flood plain adjustments and employment of appropriate technologies for flood mitigation.*

Unit – I
Disaster: Classifications - Causes - Impacts including social, economical, political, environmental, health, psychosocial, etc.
Seismic performance of buildings: case studies of major earthquake sin the country, damage to buildings, damage patterns, performance of non-engineered buildings-Introduction to repair and rehabilitation of structures.

Unit – II
Quality assurance for concrete – Strength, Durability and Thermal properties of concrete. Damage Assessment**:** - Condition assessment and distress, Purpose of assessment, Rapid assessment - diagnostic techniques, Investigation of damage, , Evaluation of surface and structural cracks, Damage assessment procedure, destructive, non-destructive and semi destructive testing systems, Procedure for evaluating damaged of structure.

Unit – III
Repair, Rehabilitation And Retrofitting Techniques : Repair materials, Common types of repairs – Repair in concrete structures – Repairs in under water structures – Guniting – Shot create –Underpinning, Strengthening of Structural elements, Repair of structures distressed due to corrosion, fire, Leakage, earthquake, Retrofitting techniques

Unit – IV
Introduction to Disasters: Hazard, Vulnerability, Resilience, Risks.-Disaster- Different types of cold wave-heat wave- droughts- floods-Effect of climate change on Processes.
Flood characteristics and forecasting: Measureable features of a flood (Elevation, discharge, volume, and duration), flood forecasting (unit hydrograph method, meteorological and snow data, and snow field air temperatures), operation of flood forecasting systems.
Space-time characteristics of rainfall: Policy criteria for design flood of a major and minor reservoir, spillways, diversion dams and barrages, design flood criteria for dams and other hydraulic structures (CWC recommendations).

Unit – V
Flood Routing: Mathematics of flood routing, various methods of flood routing, Hydrologic and Hydraulic routing.
Flood mitigation: flood ways, channel improvement, evacuation and flood proofing, land management, flood plain management, estimating benefits of flood mitigation.
Flood plain adjustments and regulations: Results of controlling floods, alternatives to controlling floods, range of possible adjustments, practical range of choice, critical characteristics of flood hazards.

Suggested Reading:

1	Barry A. Richardson, "Defects and Deterioration in Buildings", E &FN Spon Press, London, 1991.
2	J. H. Bungey, "Testing of Concrete in Structures", Chapman and Hall,New York, 1989.
3	"A.R. Santakumar, "Concrete Technology", Oxford University Press,New Delhi, 2006.
4	"Pankaj Agarwal and Manish Shrihkande (2006). "Earthquake Resistance DesignofStructures." PrenticeHall of India.
5	"Ravishankar.K.,Krishnamoorthy.T.S, "Structural Health Monitoring, Repair and Rehabilitation of Concrete Structures", Allied Publishers, 2004. New Technological Age",2016.
6	CPWD and Indian Buildings Congress, Hand book on Seismic Retrofit of Buildings, Narosa Publishers, 2008.

AC 033	**SANSKRIT FOR TECHNICAL KNOWLEDGE**					
(AUDIT COURSE - II)						
Pre-requisites			**L**	**T**	**P**	**C**
			2	-		0
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	*To get a working knowledge in illustrious Sanskrit, the scientific language in the world*
2	*To make the novice Learn the Sanskrit to develop the logic in mathematics, science & other subjects*
3	*To explore the huge knowledge from ancient Indian literature*

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	*Develop passion towards Sanskrit language*
CO-2	*Decipher the latent engineering principles from Sanskrit literature*
CO-3	*Correlates the technological concepts with the ancient Sanskrit history.*
CO-4	*Develop knowledge for the technological progress*
CO-5	*Explore the avenue for research in engineering with aid of Sanskrit*

Unit – I

Introduction to Sanskrit Language: Sanskrit Alphabets-vowels-consonants- significance of Amarakosa-parts of Speech-Morphology-creation of new words-significance of synonyms-sandhi-samasa-sutras-active and passive Voice-Past/Present/Future Tense-Syntax-Simple Sentences (elementary treatment only)

Unit – II

Role of Sanskrit in Basic Sciences: Brahmagupthas lemmas (second degree indeterminate equations), sum of squares of n-terms of AP- sulba, sutram or baudhayana theorem (origination of Pythagoras theorem)-value of pie-Madhava's sine and cosine theory (origination of Taylor's series). The measurement system-time-mass-length-temp, Matter elasticity-optics-speed of light (origination of Michaelson and Morley theory).

Unit – III

Role of Sanskrit in Engineering-I (Civil, Mechanical, Electrical and Electronics Engineering): Building construction-soil testing-mortar-town planning-Machine definition-crucible-furnace-air blower- Generation of electricity in a cell-magnetism-Solar system-Sun: The source of energy, the earth-Pingalachandasutram (origination of digital logic system)

Unit – IV

Role of Sanskrit in Engineering-II (Computer Science Engineering & Information Technology): Computer languages and the Sanskrit languages-computer command words and the vediccomm and words-analogy of pramana in memamsa with operators in computer language-sanskrit analogy of physical sequence and logical sequence, programming.

Unit – V
*Role of Sanskrit in Engineering-III (Bio-technology and Chemical Engineering):*Classification of plants- plants, the living-plants have senses-classification of living creatures, Chemical laboratory location and layout- equipment-distillation vessel-kosthiyanthram

Suggested Reading:

1	M Krishnamachariar, "*History of Classical Sanskrit Literature",* TTD Press, 1937.
2	M.R. Kale, "*A Higher Sanskrit Grammar: For the Use of School and College Students*", MotilalBanarsidass Publishers, 2015.
3	Kapail Kapoor, "*Language, Linguistics and Literature: The Indian Perspective",* ISBN- 10: 8171880649, 1994.
4	"*Pride of India*", SamskritaBharati Publisher, ISBN: 81-87276 27-4, 2007.
5	Shri Rama Verma, "*Vedas the source of ultimate science",* Nag publishers, 2005.

AC 034	**VALUE EDUCATION**					
(AUDIT COURSE - II)						
Pre-requisites			**L**	**T**	**P**	**C**
			2	-		0
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	*Understand the need and importance of Values for self-development and for National development.*
2	*Imbibe good human values and Morals*
3	*Cultivate individual and National character.*

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	*Gain necessary Knowledge for self-development*
CO-2	*Learn the importance of Human values and their application in day to day professional life.*
CO-3	*Appreciate the need and importance of interpersonal skills for successful career and social life*
CO-4	*Emphasize the role of personal and social responsibility of an individual for all-round growth.*
CO-5	*Develop a perspective based on spiritual outlook and respect women, other religious practices, equality, non-violence and universal brotherhood.*

Unit – I

Human Values, Ethics and Morals: Concept of Values, Indian concept of humanism, human values; Values for self-development, Social values, individual attitudes; Work ethics, moral and non- moral behaviour, standards and principles based on religion, culture and tradition.

Unit – II

Value Cultivation, and Self-management: Need and Importance of cultivation of values such as Sense-of Duty, Devotion to work, Self-reliance, Confidence, Concentration, Integrity & discipline, and Truthfulness.

Unit – III

Spiritual outlook and social values: Personality and Behavior, Scientific attitude and Spiritual (soul) outlook; Cultivation of Social Values Such as Positive Thinking, Punctuality, Love & Kindness, avoiding fault finding in others, Reduction of anger, forgiveness, Dignity of labour, True friendship, Universal brotherhood and religious tolerance.

Unit – IV

Values in Holy Books: Self-management and Good health; internal & external cleanliness, Holy books versus Blind faith, Character and Competence, Equality, Nonviolence, Humility, Role of Women.

Unit – V
Dharma, Karma and Guna: Concept of soul; Science of Reincarnation, Character and Conduct, Concept of Dharma; Cause and Effect based Karma Theory; The qualities of Devine and Devilish; Satwic, Rajasic and Tamasicgunas.

Suggested Reading:

1	Chakroborty, S.K., *"Values & Ethics for organizations Theory and practice*", Oxford University Press, New Delhi, 1998.
2	Jaya Dayal Goyandaka, "*Srimad Bhagavad Gita with Sanskrit Text*", Word Meaning and Prose Meaning‖, Gita Press, Gorakhpur, 2017.

AC 035	**STRESS MANAGEMENT BY YOGA**					
	(AUDIT COURSE - II)					
Pre-requisites			**L**	**T**	**P**	**C**
			2	-		0
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	*Creating awareness about different types of stress and the role of yoga in the management of stress.*
2	*Promotion of positive health and overall wellbeing (Physical, mental, emotional, social and spiritual).*
3	*Prevention of stress related health problems by yoga practice.*

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	*To understand yoga and its benefits.*
CO-2	*Enhance Physical strength and flexibility.*
CO-3	*Learn to relax and focus.*
CO-4	*Relieve physical and mental tension through Asanas*
CO-5	*Improve work performance and efficiency.*

Unit – I
Meaning and definition of Yoga - Historical perspective of Yoga - Principles of Astanga Yoga by Patanjali.

Unit – II
Meaning and definition of Stress - Types of stress - Eustress and Distress. Anticipatory Anxiety and Intense Anxiety and depression. Meaning of Management- Stress Management.

Unit – III
Concept of Stress according to Yoga - Stress assessment methods - Role of Asana, Pranayama and Meditation in the management of stress.

Unit – IV
Asanas- (5 Asanas in each posture) - Warm up - Standing Asanas - Sitting Asanas - Prone Asanas - Supine asanas - Surya Namaskar.

Unit – V
Pranayama- Anulom and Vilom Pranayama - Nadishudhi Pranayama – Kapalabhati-Pranayama - Bhramari Pranayama - Nadanusandhana Pranayama.
Meditation techniques: Om Meditation - Cyclic meditation : Instant Relaxation technique (QRT), Quick Relaxation Technique (QRT), Deep Relaxation Technique (DRT).

Suggested Reading:

1	"Yogic Asanas for Group Training - Part-I": Janardhan Swami YogabhyasiMandal, Nagpur
2	"Rajayoga or Conquering the Internal Nature" by Swami Vivekananda, Advaita Ashrama (Publication Department), Kolkata
3	Nagendra H.R and Nagaratna R, "Yoga Perspective in Stress Management", Bangalore, Swami Vivekananda Yoga Prakashan

Web resource:

1	https://onlinecourses.nptel.ac.in/noc16_ge04/preview
2	https://freevideolectures.com/course/3539/indian-philosophy/11

AC 036	**PERSONALITY DEVELOPMENT THROUGH LIFE ENLIGHTENMENT SKILLS**					
	(AUDIT COURSE - II)					
Pre-requisites			**L**	**T**	**P**	**C**
			2	-		0
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	*To learn to achieve the highest goal happily*
2	*To become a person with stable mind, pleasing personality and determination*
3	*To awaken wisdom in students*

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	*Develop their personality and achieve their highest goal of life.*
CO-2	*Lead the nation and mankind to peace and prosperity.*
CO-3	*To practice emotional self regulation.*
CO-4	*Develop a positive approach to work and duties.*
CO-5	*Develop a versatile personality.*

Unit – I
Neetisatakam – Holistic development of personality - Verses 19, 20, 21, 22 (Wisdom) - Verses 29, 31, 32 (Pride and Heroism) - Verses 26,28,63,65 (Virtue)

Unit – II
Neetisatakam – Holistic development of personality (cont'd) - Verses 52, 53, 59 (dont's) - Verses 71,73,75& 78 (do's) - Approach to day to day works and duties.

Unit – III
Introduction to Bhagavad Geetha for Personality Development - Shrimad Bhagawad Geeta: Unit 2 – Verses 41, 47, 48 - Unit 3 – Verses 13,21,27,35 - Unit 6 – Verses 5,13,17,23,35 - Unit 18 – Verses 45, 46, 48 Unit – 6: Verses 5, 13, 17, 23, 35; Unit – 18: Verses 45, 46, 48.

Unit – IV
Statements of basic knowledge - Shrimad Bhagawad Geeta: Unit 2- Verses 56, 62,68 - Unit 12 – Verses 13, 14, 15, 16, 17, 18 - Personality of Role model from Shrimad Bhagawat Geeta.

Unit – V
Role of Bahgavadgeeta in the present scenario - Unit 2 – Verses 17 – Unit 3 – Verses 36, 37, 42 - Unit 4 – Verses 18, 38, 39 - Unit 18 – Verses 37, 38, 63.

Suggested Reading:

1	"Srimad Bhagavad Gita" by Swami Swarupananda Advaita Ashram (Publication Department), Kolkata.
2	Bhartrihari's Three Satakam (Niti-sringar-vairagya) by P.Gopinath, Rashtriya Sanskrit, Sansthanam, New Delhi.

Web resource:

1	NTPEL:http://nptel.ac.in/downloads/109104115

AC 037	CONSTITUTION OF INDIA					
	(AUDIT COURSE - II)					
Pre-requisites			**L**	**T**	**P**	**C**
			2	-		0
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	*The history of Indian Constitution and its role in the Indian democracy.*
2	*Address the growth of Indian opinion regarding modern Indian intellectuals' constitutional role and entitlement to civil and economic rights as well as the emergence of nationhood in the early years of Indian nationalism.*
3	*Have knowledge of the various Organs of Governance and Local Administration.*

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	*Understand the making of the Indian Constitution and its features.*
CO-2	*Understand the Rights of equality, the Right of freedom and the Right to constitutional remedies.*
CO-3	*Have an insight into various Organs of Governance - composition and functions*
CO-4	*Understand powers and functions of Municipalities, Panchayats and Co-operative Societies.*
CO-5	*Understand Electoral Process, special provisions.*

Unit – I
History of making of the Indian constitutions: History, Drafting Committee(Composition & Working). **Philosophy of the Indian Constitution**: Preamble, Salient Features.

Unit – II
Contours of Constitutional Rights and Duties Fundamental Rights, Right to Equality, Right to Freedom, Right against Exploitation, Right to Freedom of Religion, Cultural and Educational Rights, Right to Constitutional Remedies, Directive Principles of State Policy, Fundamental Duties

Unit – III
Organs of Governance": Parliament: Composition, Qualifications, Powers and Functions, Union executives : President, Governor, Council of Ministers, Judiciary, appointment and transfer of judges, qualifications, powers and functions.

Unit – IV
Local Administration - District's Administration head: Role and importance. Municipalities: Introduction, ayor and role of Elected Representative, CEO of Municipal Corporation. Panchayati Raj: Introduction, PRI: Zilla Panchayat, Elected Officials and their roles, CEO Zilla Panchayat: positions and role. Block level: Organizational Hierarchy (Different departments) Village level: role of elected and appointed officials. Importance of grass root democracy.

Unit – V
Election commission: Election Commission: Role and functioning, Chief Election Commissioner and Election Commissioners, State Election Commission :Role and functioning. Institute and Bodies for the welfare of SC/ST/OBC and women**.**

Suggested Reading:

1	The Constitution of India", 1950 (Bare Act), Government Publication
2	Dr. S. N. Busi, Dr. B. R. Ambedkar, "Framing of Indian Constitution", 1st Edition, 2015.
3	M. P. Jain, "Indian Constitution Law", 7th Edn., Lexis Nexis, 2014
4	D.D. Basu, "Introduction to the Constitution of India", Lexis Nexis, 2015.

Web resource:

1	http://www.nptel.ac.in/courses/103107084/Script.pdf

AC 038	**PEDAGOGY STUDIES**					
	(AUDIT COURSE - II)					
Pre-requisites			**L**	**T**	**P**	**C**
			2	-		0
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	*To present the basic concepts of design and policies of pedagogy studies.*
2	*To provide understanding of the abilities and dispositions with regard to teaching techniques, curriculum design and assessment practices and familiarize various theories of learning and their connection to teaching practice.*
3	*To create awareness about the practices followed by DFID, other agencies and other researchers and provide understanding of critical evidence gaps that guides the professional development*

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	*Illustrate the pedagogical practices followed by teachers in developing countries both in formal and informal classrooms.*
CO-2	*Examine the effectiveness of pedagogical practices.*
CO-3	*Understand the concept, characteristics and types of educational research and perspectives of research.*
CO-4	*Describe the role of classroom practices, curriculum and barriers to learning.*
CO-5	*Understand Research gaps and learn the future directions.*

Unit – I
Introduction and Methodology: Aims and rationale, Policy background, Conceptual framework and terminology - Theories of learning, Curriculum, Teacher education - Conceptual framework, Research questions, Overview of methodology and Searching.

Unit – II
Thematic Overview: Pedagogical practices followed by teachers in formal and informal classrooms in developing countries - Curriculum, Teacher education.

Unit – III
*Evidence on the Effectiveness of Pedagogical Practices***:** Methodology for the in depth stage: quality assessment of included studies - How can teacher education (curriculum and Practicum) and the school curriculum and guidance material best support effective pedagogy? - Theory of change - Strength and nature of the body of evidence for effective pedagogical practices - Pedagogic theory and pedagogical approaches – Teachers attitudes and beliefs and pedagogic strategies.

Unit – IV
Professional Development: alignment with classroom practices and follow up support - Support from the head teacher and the community – Curriculum and assessment - Barriers to learning: Limited resources and large class sizes.

Unit – V
Research Gaps and Future Directions: Research design – Contexts – Pedagogy - Teacher education - Curriculum and assessment – Dissemination and research impact.

Suggested Reading:

1	Ackers J, Hardman F, *"Classroom Interaction in Kenyan Primary Schools, Compare*", 31 (2): 245 – 261, 2001.
2	Agarwal M, *"Curricular Reform in Schools: The importance of evaluation*", Journal of Curriculum Studies, 36 (3): 361 – 379, 2004.
3	Akyeampong K, "*Teacher Training in Ghana – does it count? Multisite teacher education research project (MUSTER)",* Country Report 1. London: DFID, 2003.
4	Akyeampong K, Lussier K, Pryor J, Westbrook J, *"Improving teaching and learning of Basic Maths and Reading in Africa: Does teacher Preparation count?"*International Journal Educational Development, 33 (3): 272- 282, 2013.
5	Alexander R J, *"Culture and Pedagogy: International Comparisons in Primary Education",* Oxford and Boston: Blackwell, 2001.
6	Chavan M, Read India: *"A mass scale, rapid, learning to read campaign",* 2003

AC 039	**E-WASTE MANAGEMENT**					
(AUDIT COURSE - II)						
Pre-requisites			**L**	**T**	**P**	**C**
			2	-		0
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	Introduction to E-Waste management
2	Understanding on resource efficiency and circular economy
3	E-waste Management rules 2016
4	RoHS compliances/directives to EEE

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	Complete understanding on E-Waste management
CO-2	Understanding on effective recycling methodologies for e-waste management
CO-3	Overall understanding about E-waste Management rules 2016 and strategies for e-waste management
CO-4	Understanding on RoHS compliances for EEE products

Unit – I
Waste Electrical and Electronic Equipment (WEEE): Flows, Quantities and Management, a Global Scenario; The Importance of Waste Management; Types of Waste- Solid and Liquid; Criteria for EEE/E-Waste Classification; Multivariate Model for E-Waste Estimation; Environmental and Health Effects of Waste Management, Inventorisation of E-Waste and Emerging trends in E-waste disposal with bench marks for depollution - global scenario; Dumping, Burning and Landfill: Impact on the Environment

Unit – II
Effective Waste Management and Disposal Strategies; Legislative Influence on Electronics Recycling; Waste Management Rules and Their Amendments; Extended Producer Responsibility (EPR) in E-Waste Management; The Role of Collective versus Individual Producer Responsibility in E-Waste Management

Unit – III
Electronic Waste: Public Health Implications; Restriction of Hazardous Substances (RoHS) Directives in Electrical and Electronic Equipment; Materials Used in Manufacturing Electrical and Electronic Products

Unit – IV
Recycling and Resource Management: Ecological and Economical Valuation; Life Cycle Assessment (LCA) Approach to Waste Management System; Environmental Incentives for Recycling and Life Cycle Analysis of Materials Recycling Electronic Waste: Challenges and Opportunities for Sustainable Management; Resource Recovery from E-waste: Efficiency and Circular Economy; Integrated Approach to E-Waste Recycling: Recycling and Recovery Technologies, Recycling and Recovery Technologies.

Unit – V
Cases studies: E-waste Generation, collection and recycling

Suggested Reading:

1	Electronic Waste Management and Treatment Technology, Editors: Majeti NarasimhaVara Prasad Meththika Vithanage
2	Electronic Waste Management, Edited by R. E. Hester, R. M. Harrison, RSC Publishing 2009
3	Solid Waste Technology & Management, Christensen, T., Ed., Wiley and Sons., 2011
4	Electronics Waste Management: An India Perspective. Front Cover. Sandip Chatterjee. Lap Lambert Academic Publishing GmbH KG, 2010 - Electronic
5	Handbook of Electronic Waste Management, International Best Practices and Case studies, Elsevier, 2019
6	E-waste: Implications, regulations, and management in India and current global best practices. Author(s): Rakesh Johri, TERI Press

ME281	**DISSERTATION PHASE-I**					
Pre-requisites	-		**L**	**T**	**P**	**C**
			-	-	20	10
Evaluation	**SEE**	-	**CIE**	100 Marks		

Course Objectives:	
1	Identification of the research problem
2	Discussion of literature survey.
3	Learn the resources available at the college and outside for pursuing project
4	Learn to select appropriate software and procedure
5	Learn to document results and arrive at required conclusions

Course Outcomes:	
CO-1	Identification of the objectives of the Research Problem.
CO-2	Ability to update the latest literature in chosen area of research & establishment of the scope of work.
CO-3	Development of the methodology for the chosen research problem and perform Basic theoretical / experiment studies.
CO-4	Identification of the objectives of the Research Problem. Ability to update the latest literature in chosen area of research & establishment of the scope of work.
CO-5	Interpret the results and arrive at the relevant conclusions and defend work in front of technically qualified audience Document the findings as a technical report with proper references

Program Articulation Matrix

Course outcome	**Program outcome**				
	PO1	**PO2**	**PO3**	**PO4**	**PO5**
CO1			2	3	1
CO2			2	3	1
CO3			2	3	1
CO4			2	3	1
CO 5			2	3	1

Contents:

Each student will be attached to a faculty member/guide for project. The student will carry out the project which may be development of Software / Hardware / Simulation studies / Design analysis / Experimental related to his/her specialization. The work will be monitored regularly by the guide.

At the end of the semester student will write the report on the work done and submit to the guide. Student has to present his/her work before two faculty members (one guide and other to be appointed by chairman BoS) on a fixed day during last week of the semester in which project is offered. The sessional marks will be awarded jointly by these examiners based on the report, presentation and viva voice

GUIDELINES

1. The Major Project Phase I Work should preferably be a problem with research potential and should involve scientific research, design, generation/collection and analysis of data, determining solution and must preferably bring out the individual contribution.
2. Seminar should be based on the area in which the candidate has undertaken the dissertation work as per the common instructions for all branches of Master of Engineering
3. The examination shall consist of the preparation of report consisting of a detailed problem statement and a literature review.
4. The preliminary results (if available) of the problem may also be discussed in the report.
5. The work has to be presented in front of the examiners panel set by Head and Faculty Advisor.
6. The candidate has to be in regular contact with his guide and the topic of dissertation must be mutually decided by the guide and student.

SEMESTER-IV

ME282	**DISSERTATION PHASE-II**					
Pre-requisites	-		**L**	**T**	**P**	**C**
			-	-	32	16
Evaluation	**SEE**	100 Marks	**CIE**	100 Marks		

Course Objectives:	
1	Identification of the research problem
2	Discussion of literature survey. Learn the resources available at the college and outside for pursuing project
	Learn to select appropriate software and procedure
	Learn to document results and arrive at required conclusions

Course Outcomes:	
CO-1	Expand the defined Research Problem for the dissertation work.
CO-2	Conduct of Laboratory / analytical / software studies, use different experimental techniques & software/ computational / analytical tools, Design and develop an experimental set up / equipment / test rig.
CO-3	Analysis of Data, development of models, offer solutions to the research problem and provide conclusions of the work.
CO-4	Conduct tests on existing set ups/equipment
CO-5	Draw logical conclusions from the results after analyzing them and technical report writing.

Program Articulation Matrix

Course outcome	**Program Outcome**				
	PO1	**PO2**	**PO3**	**PO4**	**PO5**
CO1	2	2	2	3	1
CO2	2	2	2	3	1
CO3	2	2	2	3	1
CO4	2	2	2	3	1
CO 5	2	2	2	3	1

Contents:

The student will carry out the project under allotted supervisor, which may be development of Software / Hardware / Simulation studies / Design analysis / Experimental related to his/her specialization. The work will be monitored regularly by the guide. At the end of the semester student will write the report on the work done and submit to the guide. Student has to present his/her work before two faculty members (one guide and other to be appointed by chairman BoS on a fixed day during last week of the semester in which project is offered. The final marks will be allotted based on the report, presentation and viva voce conducted by the external examiner whose name is suggested by Chairman BoS

Guidelines

1. It is a continuation of Major Project Phase I work started in semester III.
2. The dissertation should be presented in standard format as provided by the department.
3. The candidate has to prepare a detailed project report consisting of introduction of the problem, problem statement, literature review, objectives of the work, methodology (experimental set up or numerical details as the case may be) adopted & Result analysis.
4. The report must bring out the conclusions of the work and future scope for the study and also should be properly referenced.
5. Student has to submit the report in prescribed format and also present a seminar.
6. Student should present a Seminar in front of Internal committee consisting of Head, CBoS, Guide, Subject expert, Faculty Advisor. Further the suggestions of the committee have to be incorporated in the final Report.
7. The final work has to be presented in front of the examiners panel consisting of an approved external examiner, an internal examiner and a guide, co-guide etc. as decided by the Head and Faculty Advisor.
8. The candidate has to be in regular contact with his/her guide.