PUDUCHERRY TECHNOLOGICAL UNIVERSITY
PUDUCHERRY–605014

(A Technological University of Government of Puducherry)

Curriculum and Syllabi

of

M.Tech in Energy Technology

(With effect from Academic year 2020-21)

(Approved in Sixth Academic Council Meeting held on 20th March 2021)

PROGRAM EDUCATIONAL OBJECTIVES (PEOs)

Program Educational Objectives (PEOs) are broad statements that describe the career and professional accomplishments that the program is preparing graduates to achieve. They are consistent with the mission of the Institution and Department. Department faculty members continuously worked with stakeholders (local employers, industry and R&D advisors and the alumni) to review and update them periodically. The curriculum of M.Tech. (Energy Technology) is designed to fulfill the Programme Educational Objectives (PEO) and Programme Outcomes (PO) listed below

PEO1	Expertise in the field of Energy Technology in technological enterprises, companies, organization and industries both at national and international levels**(Eminence in Energy Technology)**
PEO2	Inquisitive spirit to elicit creative and innovative outcomes through constructive efforts and analytical research in the field of Energy Technology **(Higher studies and R&D)**
PEO3	Encouragement and enthusiasm for the subject of interest and provide solid ground to respond to a lifetime of career challenges and changes through lifelong learning (**Passion for higher education**)
PEO4	Exhibit professionalism with greater responsibility in conserving energy and exercise their leadership-traits in energy management with the cognizance of energy savings and environmental issues **(Professional ethics and leadership qualities)**
PEO5	Create interest for new technologies, skills, values, and concern for social, environmental and economic sustainability (**Sustainable development**)

PROGRAMME OUTCOMES (POs)

PO1	Carryout independent research/investigation and development work to solve practical problems
PO2	Write and present a substantial technical report/document
PO3	Demonstrate a degree of mastery over Energy Technology at a level higher than the bachelors program
PO4	Design ,develop and analyze conventional, renewable and non-renewable energy systems for performance enhancement
PO5	Identify new and sustainable energy sources and develop effective energy conversion system with concerns on environment protection
PO6	Engage in lifelong learning to develop new materials for energy systems adhering to professional ethics and safety

CURRICULUM

Distribution of Credits among the subjects grouped under various categories:

Courses are grouped under various categories and the credits to be earned in each category of courses are as follows:

Sl.No.	Category	Credits	Course Category Code (CCC)
1	Programme Core Course	24	PCC
2	Programme Specific Elective Courses	15	PSE
3	Open Elective Courses	03	OEC
4	Professional Activity Courses (Project Work, Seminar)	28	PAC
5	Mandatory Audit Courses	Non Credit	MAC
	Total	**70**	

Semester-wise Courses and Credits

Semester I

Course Code	Course	CCC	Periods			Credits
			L	T	P	
ME251	Thermodynamic Analysis of Energy Systems	PCC	3	0	0	3
ME252	Analysis of Heat and Mass transfer	PCC	3	0	0	3
ME253	Design of Thermal Equipment	PCC	3	0	0	3
MEZ01	Programme Specific Elective - 1	PSE	3	0	0	3
MEZ02	Programme Specific Elective - 2	PSE	3	0	0	3
ME254	Energy Engineering Laboratory	PCC	0	0	4	2
ME255	Research Methodology and IPR	PCC	2	0	0	2
AD2NN	Audit Course - I	MAC	2	0	0	0
Total			**23**			**19**

Semester II

Course Code	Course	CCC	Periods			Credits
			L	T	P	
ME256	Computational Fluid Dynamics	PCC	3	0	0	3
ME257	Modeling and simulation of Energy Systems	PCC	3	0	0	3
ME258	Optimization Techniques	PCC	3	0	0	3
MEZ03	Programme Specific Elective -3	PSE	3	0	0	3
MEZ04	Programme Specific Elective - 4	PSE	3	0	0	3
ME259	Computational Techniques Laboratory	PCC	0	0	4	2
ME260	Mini Project and Seminar	PAC	0	0	4	2
AD2NN	Audit Course - II	MAC	2	0	0	0
Total			**25**			**19**

Semester III

Course Code	Course	CCC	Periods			Credits
			L	T	P	
MEZ05	Programme Specific Elective - 5	PSE	3	0	0	3
OE2NN	Open Elective	OEC	3	0	0	3
ME261	Dissertation – Phase I	PAC	0	0	20	10
Total			**26**			**16**

Semester IV

Course Code	Course	CCC	Periods			Credits
			L	T	P	
ME262	Dissertation – Phase II	PAC	0	0	32	16
Total			**32**			**16**

Total Credits: 70

Audit Courses (MAC)

AD201	English for Research Paper Writing
AD202	Disaster Management
AD203	Value Education
AD204	Constitution of India
AD205	Pedagogy Studies
AD206	Stress Management by Yoga

Open Elective Courses (OEC)

OE201	Business Analytics (IT)
OE202	Industrial Safety and Maintenance (ME)
OE203	Operations Research (ME)
OE204	Cost Management of Engineering Projects (CE)
OE205	Composite Materials (PH)
OE206	Waste to Energy (CE)

Programme Specific Electives (PSE)

PSE - 1/PSE- 2	**MEZ01**	Advanced Fluid Mechanics
	MEZ02	Advanced Refrigeration and Cryogenics
	MEZ03	Fuels and Combustion
	MEZ04	Biomass Conversion Systems
	MEZ05	Cogeneration Technology
	MEZ06	Electric Vehicle and Autonomous Transport
	MEZ07	Energy Conversion Systems
	MEZ08	Alternative Fuels and their Applications in combustion systems
PSE -3/PSE - 4	**MEZ09**	Hydrogen Energy and Fuel Cells
	MEZ10	Micro –Nano Scale Fluid Flow and Heat Transfer
	MEZ11	Energy Conservation and Management Systems
	MEZ12	Nuclear Power Engineering
	MEZ13	Power Plant Management and Economics
	MEZ14	Thermal Turbomachines
	MEZ15	Solar Power Technology
	MEZ16	Ultra supercritical Power Plants and Materials
PSE - 5	**MEZ17**	Wind Energy Technology
	MEZ18	Non equilibrium and Quantum Thermodynamics
	MEZ19	Advanced and Applied Computational Fluid Dynamics
	MEZ20	Multiscale and Multi physics Simulation of Energy Systems

Department: **Mechanical Engineering**		Programme: **M.Tech.(Energy Technology)**							
Semester: **First**		Course Category Code:**PCC**				Semester Exam Type: **TY**			
Course Code	Course Name	Periods / Week			Credit	Maximum Marks			
		L	T	P		CA	SE	TM	
ME251	**Thermodynamic Analysis of Energy Systems**	**3**	**-**	**-**	**3**	**40**	**60**	**100**	
Prerequisite	Engineering Thermodynamics, Heat and mass transfer, Power plant engineering.								

Course Outcomes		
	CO1	Students understand the significance of thermodynamic properties and thermodynamic relations.
	CO2	Gain ability to calculate heat transfer and work transfer and efficiency
	CO3	Gain ability in exergy calculations of various thermodynamic systems.
	CO4	Gain ability in exergy analysis of thermal and chemical plants.
	CO5	Gain ability in thermodynamic optimization.

UNIT I	**Periods : 9**
Review of thermodynamic properties, process and laws Thermodynamic properties: pressure, volume, temperature, specific heats, internal energy, enthalpy and entropy –.Thermodynamic processes and cycles – First law and its significance – Energy balance equations for closed and open systems – Comparison of work and heat transfer for different processes – First law efficiency	**CO1**
UNIT II	**Periods : 9**
Evaluation of systems with second laws Thermodynamic relations: Maxwell relations – ClausiusClapeyron equation – Joule-Thomson coefficient – Gibb's function – Helmholtz function – Generalized relations for specific heats, internal energy, enthalpy and entropy. Significance of Second law – Carnot cycle – Second law analysis of reversible and irreversible processes and cycles – Maximum work.	**CO2**
UNIT III	**Periods : 9**
Elements of exergy analysis Control mass analysis – Control region analysis – Reversibility and Irreversibility – Entropy generation – Exergy: Classification – Exergy analysis of processes: Expansion, Compression, Heat exchange, Mixing and separation, Combustion, Chemical reactions – Material and exergy balances of energy systems – Kinds and characteristics of exergy losses – Exergy efficiency – Thermodynamic non-equivalence of exergy and exergy losses	**CO3**
UNIT IV	**Periods : 9**
Exergy analysis of thermal and chemical plants: Analysis of thermal power plant: boiler, turbine, condenser, system cycle: Rankine cycle – Analysis of gas turbine plant: compressor, combustor, turbine, system cycle: Brayton cycle – Analysis of refrigeration plant: compressor, condenser, expansion, evaporator – Analysis of Linde air liquefaction system: compressor, heat exchanger,expansion valve – Analysis of sulphuric acid plant.	**CO4**
UNIT V	**Periods : 9**
Thermodynamic optimization of thermal systems Structural coefficients of system elements – Optimization of component geometry – Optimization of systems: Static and dynamic exergy analyses of systems with their elements connected in series and in parallel – Techno economic optimization: Exergitic and operating costing and optima – Structural method of techno-economic optimization – Autonomous method of techno-economic optimization – Exergitic costing in multi-product plants – Optimization of equipment and operating costs of pro-exergitic and anti-exergitic equipment – Cumulative Exergy– Cost diagram	**CO5**

Lecture Periods: 45	**Tutorial Periods: -**	**Practical Periods: -**	**Total Periods: 45**

Reference Books
1. Van Wylen and Sonntag, R. E., Fundamentals of Classical Thermodynamics, John Wiley & Sons, 1994. 2. Green, Don W.; Perry, Robert H., Perry's Chemical Engineers' Handbook (8th edition), McGraw Hill Book Co., New York, 2008 3. Michael, J. Moran and Howard, N. Shapiro, Fundamentals of Engineering Thermodynamics, John Wiley & Sons, New York, 1993. 4. Francis, F. Huang, Engineering Thermodynamics Fundamentals and Application, Macmillan Publishing Co., New York, 1989.

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	3	3	2
CO2	3	1	3	2	3	2
CO3	3	1	3	2	3	2
CO4	3	1	3	2	3	2
CO5	3	1	3	3	3	2

3 – High; **2** – Medium; **1** – Low

Department: **Mechanical Engineering**		Programme: **M.Tech. (Energy Technology)**						
Semester: **First**		Course Category Code: **PCC**			Semester Exam Type: **TY**			
Course Code	Course Name	Periods / Week			Credit	Maximum Marks		
		L	T	P		CA	SE	TM
ME252	**Analysis of Heat and Mass Transfer**	**3**	**-**	**-**	**3**	**40**	**60**	**100**
Prerequisite	-							

Course Outcome	**CO1**	Employ mathematical functions and heat conduction charts in tackling one dimensional , two dimensional and three-dimensional heat conduction problems
	CO2	Analyze free and forced convection problems involving complex geometries with proper boundary conditions
	CO3	Understand both the physics and the mathematical treatment of radiative heat transfer and to apply the concepts of radiation heat transfer for enclosure analysis.
	CO4	Understand physical and mathematical aspects of diffusive mass transfer.
	CO5	Understand physical and mathematical aspects of convective mass transfer.

UNIT I	**Periods** : **9**
Conductive heat transfer General differential equations for heat transfer – special forms of differential heat equations – commonly encountered boundary conditions – steady-state one-dimensional heat conduction without and with internal generation of energy – analysis of heat transfer from extended surfaces – two- and three-dimensional systems: governing equations and solution techniques – unsteady heat conduction: differential equations and analytical solutions – temperature-time charts for different geometric shapes – numerical methods for unsteady conduction analysis	**CO1**
UNIT II	**Periods** : **9**
Convective heat transfer Significance of dimensionless parameters in convective heat transfer analysis – theories of boundary layers - governing differential equations – exact analysis of laminar boundary layer – approximate integral analysis of thermal boundary layer – energy and momentum transfer analogies – analysis of turbulent flow – exact solutions convective heat transfer correlations – free convection from vertical, horizontal and inclined plates – convection within parallel channels and enclosures – forced convection for internal and external flows. Heat transfer with phase change – condensation and boiling – laminar and turbulent film condensations on vertical plates – film condensation on radial systems and horizontal tubes – heat transfer in flow boiling – heat transfer in two phase flow – heat transfer in high speed flow	**CO2**
UNIT III	**Periods** : **9**
Radiative heat transfer Thermal radiation – radiation intensity – blackbody radiation – Planck's law – Stefan-Boltzmann law –surface emission – emissivity and absorptivity of solid surfaces – Kirchoff's law – gray surface – environmental radiation - blackbody radiative heat exchange – view factor – radiative heat exchange between gray surfaces without and with radiating enclosures – radiation shields – reradiating surfaces – radiative heat exchange between surfaces with volumetric absorption of separating medium – effects of radiation from gases, vapour, clouds and luminous flames – multimode heat exchange processes and analysis.	**CO3**

UNIT IV		Periods : 9
Diffusive mass transfer Differential equations for mass transfer – special forms of differential mass-transfer equation – commonly encountered boundary conditions – steady-state molecular diffusion: one-dimensional mass transfer without and with chemical reaction – two- and three-dimensional mass transfer systems – simultaneous heat, momentum and mass transfer system – unsteady-state molecular diffusion: governing differential equation and analytical solution– concentration-time charts for mass transfer in different geometric shapes – numerical methods for transient mass transfer analysis		**CO4**
UNIT V		**Periods** : 9
Convective mass transfer Significance of dimensionless parameters in convective mass transfer analysis – theories of boundary layers – governing differential equations – exact analysis of laminar boundary layer – approximate integral analysis of thermal boundary layer – mass, energy and momentum transfer analogies – models of convective mass transfer coefficients – inter-phase mass transfer – convective mass transfer correlations: mass transfer to plates, cylinders and spheres – mass transfer in wetted-wall columns, packed and fluidized beds – mass transfer involving turbulent flow through pipes		**CO5**

Lecture Periods: 45	Tutorial Periods: -	Practical Periods: -	Total Periods: 45

Reference Books

1. Cengel,Heat and Mass Transfer, Tata Mcgraw Hill Education , Private Limited, 4th Edition.
2. J. P. Holman,Heat Transfer, Tata Mcgraw Hill Education,10th Edition.
3. Frank P. Incropera and John Wiley &David P. Dewitt., Sons - Fundamentals of Heat and Mass Transfer – 4/e, New York, 2000.
4. Mahesh M. Rathore, Engineering heat and mass transfer, Laxmi Publications (P) Ltd. 2006.
5. Dr. R. C. Sachdeva,Fundamentals of Engineering Heat and Mass transfer, New Age International,2010

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	3	3	2
CO2	3	1	3	2	3	2
CO3	3	1	3	2	3	2
CO4	3	1	3	2	3	2
CO5	3	1	3	3	3	2

3 – High; **2** – Medium; **1** – Low

<table>
<tr><td colspan="2">Department: Mechanical Engineering</td><td colspan="7">Programme: M.Tech.(Energy Technology)</td></tr>
<tr><td colspan="2">Semester: First</td><td colspan="4">Course Category Code: PCC</td><td colspan="3">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td rowspan="2">Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>ME253</td><td>Design of Thermal Equipment</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="8">NIL</td></tr>
<tr><td rowspan="5">Course Outcome</td><td>CO1</td><td colspan="7">Students can understand different types of heat exchangers and their suitability for specific application</td></tr>
<tr><td>CO2</td><td colspan="7">Students can design, estimate the performance and operational procedure for single phase heat exchangers</td></tr>
<tr><td>CO3</td><td colspan="7">Design procedures for heat exchangers with phase change will be understood by the students</td></tr>
<tr><td>CO4</td><td colspan="7">Students will able to design compact heat exchangers and regenerators.</td></tr>
<tr><td>CO5</td><td colspan="7">Design of direct contact heat exchangers and their performance can be done by the students</td></tr>
<tr><td>UNIT I</td><td colspan="6"></td><td colspan="2">Periods : 9</td></tr>
<tr><td colspan="8">Concepts and Classification
Classification – parallel flow – counter flow – cross flow – multi pass – temperature distribution – over all heat transfer co-efficient – log mean temperature distribution – LMTD method – correction for LMTD – NTU method methodology of heat exchanger calculation – fouling of heat exchanger</td><td>CO1</td></tr>
<tr><td>UNIT II</td><td colspan="6"></td><td colspan="2">Periods : 9</td></tr>
<tr><td colspan="8">Heat exchangers with single phase flow
Double pipe heat exchangers – applications and design parameters – types available. Shell and tube heat exchangers with single phase flow – design procedure – flow arrangement for increased heat recovery.</td><td>CO2</td></tr>
<tr><td>UNIT III</td><td colspan="6"></td><td colspan="2">Periods : 9</td></tr>
<tr><td colspan="8">Heat exchangers with phase change
Types of condensers and their selection – design procedures – types of evaporators – shell and tube re-boilers – types and thermal design</td><td>CO3</td></tr>
<tr><td>UNIT IV</td><td colspan="6"></td><td colspan="2">Periods : 9</td></tr>
<tr><td colspan="8">Compact heat exchangers and regenerators
Compact heat exchanger – introduction - plate heat exchangers – heat transfer correlations – methods of surface area calculation - finned tube heat exchangers – application of common fin tubes – fin efficiency and temperature distribution in fin tubes – thermal rating of fin tube heat exchangers – regenerators and thermal energy storage – basic concepts and classification – calculation of regenerator thermal performance.</td><td>CO4</td></tr>
<tr><td>UNIT V</td><td colspan="6"></td><td colspan="2">Periods : 9</td></tr>
<tr><td colspan="8">Direct contact Heat Exchangers
Types of cooling towers – packing region – features of natural and mechanical draft towers – thermal performance of natural and forced draft cooling towers.</td><td>CO5</td></tr>
<tr><td colspan="2">Lecture Periods: 45</td><td colspan="2">Tutorial Periods: -</td><td colspan="3">Practical Periods: -</td><td colspan="2">Total Periods: 45</td></tr>
</table>

Reference Books
1. Martin, H., - Heat Exchangers, Hemisphere Publishing Corporation, 1992. 2. Kakac, S., R. K. Shahand A. E. Bergles, - Low Reynolds Number Flow Heat Exchangers, Hemisphere Publishing Corporation, 1983. 3. Hewitt, G. F., et. al., Process Heat Transfer, CRC Press, 1994. 4. Schlunder, E.U., - et al., Heat Exchanger Design Hand Book - Vols. 1-5, Hemisphere Publishing Corp., NewYork, 1983.

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	3	3	2
CO2	3	1	3	2	3	2
CO3	3	1	3	2	3	2
CO4	3	1	3	2	3	2
CO5	3	1	3	3	3	2

3 – High; **2** – Medium; **1** – Low

<table>
<tr><td colspan="2">Department: Mechanical Engineering</td><td colspan="7">Programme: M.Tech.(Energy Technology)</td></tr>
<tr><td colspan="2">Semester: First</td><td colspan="4">Course Category Code: PCC</td><td colspan="3">Semester Exam Type: LB</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td rowspan="2">Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>ME254</td><td>Energy Engineering Laboratory</td><td>-</td><td>-</td><td>4</td><td>2</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="8">Nil</td></tr>
<tr><td rowspan="4">Course Outcome</td><td>CO1</td><td colspan="7">Able to apply thermodynamic principle and laws in thermal systems like steam boiler, R&AC</td></tr>
<tr><td>CO2</td><td colspan="7">Able to apply thermodynamic principle and laws in thermal systems like IC engines</td></tr>
<tr><td>CO3</td><td colspan="7">Able to measure various fuel properties</td></tr>
<tr><td>CO4</td><td colspan="7">Able to understand the principle of working and performance of renewable energy systems</td></tr>
<tr><td colspan="9">List of Experiments</td></tr>
<tr><td colspan="8">1. Determination of heating/cooling load for the given space to be air-conditioned.
2. Performance test on Air Conditioning system.
3. Performance test on Refrigeration system.
4. Aerodynamic study on Aerofoil and Cylinder (Pressure and Velocity distribution)
5. Study of energy utilization in a Steam Boiler.</td><td>CO1</td></tr>
<tr><td colspan="8">6.Energy balance test on given Petrol engine.
7. Energy balance test on given Diesel engine.
8. Pressure Time Diagram using Pressure Transducer and Charge Amplifier of a SI Engine</td><td>CO2</td></tr>
<tr><td colspan="8">9. Determination of Calorific value of gaseous fuel using Junkers Gas Calorimeter.
10. Determination of Calorific value of solid/liquid fuel using Bomb Calorimeter.
11. Determination of moisture content of given coal/biomass samples
12. Determination of ash content of given coal/biomass samples</td><td>CO3</td></tr>
<tr><td colspan="8">13. Performance test on solar water heating system/solar still
14. Performance test on a pyrolysis unit
15. Performance test on photovoltaic system
16. Performance test on cook-stoves
17. Study of gasifier unit</td><td>CO4</td></tr>
<tr><td colspan="2">Lecture Periods: -</td><td colspan="2">Tutorial Periods: -</td><td colspan="2">Practical Periods: 60</td><td colspan="3">Total Periods: 60</td></tr>
</table>

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	2	3	2
CO2	3	2	3	2	3	2
CO3	3	2	3	2	3	2
CO4	3	2	3	3	3	2

3 – High; **2** – Medium; **1** – Low

Department: **Mechanical Engineering**		Programme: **M.Tech. (Energy Technology)**						
Semester: **First**		Course Category Code: **PCC**				Semester Exam Type: **TY**		
Course Code	Course Name	Periods / Week			Credit	Maximum Marks		
		L	T	P		CA	SE	TM
ME255	**Research Methodology and IPR**	**2**	**-**	**-**	**2**	**40**	**60**	**100**
Prerequisite	**NIL**							

Course Outcome	**CO1**	Able to understand different types of researches and their difference
	CO2	Able to identify the research gap.
	CO3	Can design the experiments and analyze the experimental data
	CO4	Will effectively present Dissertation and Research Papers.
	CO5	Can prepare Patent Disclosure and can justify Ethics in research

UNIT I	**Periods** : **6**
Meaning of Research, Types of Research, Research Process, Problem definition, Objectives of Research, Research Questions, Research design, Approaches to Research, Quantitative vs. Qualitative Approach, Understanding Theory, Building and Validating Theoretical Models, Exploratory vs. Confirmatory Research, Experimental vs Theoretical Research, Importance of reasoning in research	**CO1**
UNIT II	**Periods** : **6**
Problem Formulation, Understanding Modeling & Simulation, Conducting Literature Review, Referencing, Information Sources, Information Retrieval, Role of libraries in Information Retrieval, Tools for identifying literatures, Indexing and abstracting services, Citation indexes	**CO2**
UNIT III	**Periods** :**6**
Experimental Research: Cause effect relationship, Development of Hypothesis, Measurement Systems Analysis, Error Propagation, Validity of experiments, Statistical Design of experiments, Field Experiments, Data/Variable Types & Classification, Data collection, Numerical and Graphical Data Analysis: Sampling, Observation, Surveys, Inferential Statistics, and Interpretation of Results	**CO3**
UNIT IV	**Periods** : **6**
Preparation of Dissertation and Research Papers, Tables and illustrations, Guidelines for writing the abstract, introduction, methodology, results and discussion, conclusion sections of a manuscript. References, Citation and listing system of documents.	**CO4**
UNIT V	**Periods** : **6**
Intellectual property rights (IPR) - patents-copyrights-Trademarks-Industrial design geographical indication. Preparation of Patent Disclosure. Ethics of Research- Scientific Misconduct- Forms of Scientific Misconduct. Plagiarism, Unscientific practices in thesis work, Ethics in science.	**CO5**

Lecture Periods: 30	**Tutorial Periods: -**	**Practical Periods: -**	**Total Periods: 30**

Reference Books
1. Bordens, K. S. and Abbott, B. B., “Research Design and Methods – A Process Approach”, 8th Edition, McGraw-Hill, 2011 2. C. R. Kothari, “Research Methodology – Methods and Techniques”, 2nd Edition, New Age International Publishers 3. Davis, M., Davis K., and Dunagan M., “Scientific Papers and Presentations”, 3rd Edition, Elsevier Inc. 4. Michael P. Marder,“ Research Methods for Science”, Cambridge University Press, 2011 5. T. Ramappa, “Intellectual Property Rights Under WTO”, S. Chand, 2008 6. Robert P. Merges, Peter S. Menell, Mark A. Lemley, “Intellectual Property in New Technological Age”. Aspen Law & Business; 6 edition July 2012

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	-	-	3
CO2	3	3	3	-	-	3
CO3	3	3	3	-	-	3
CO4	3	3	3	-	-	3
CO5	3	3	3	-	-	3

<table>
<tr><td colspan="2">Department: Mechanical Engineering</td><td colspan="7">Programme: M.Tech.(Energy Technology)</td></tr>
<tr><td colspan="2">Semester: Second</td><td colspan="4">Course Category Code:PCC</td><td colspan="3">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td rowspan="2">Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>ME256</td><td>Computational Fluid Dynamics</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="8">Fluid Mechanics, Engineering thermodynamics and PD Equations.</td></tr>
<tr><td rowspan="5">Course Outcome</td><td>CO1</td><td colspan="7">Explain the types of partial differential equations.</td></tr>
<tr><td>CO2</td><td colspan="7">Understand various types of discretization</td></tr>
<tr><td>CO3</td><td colspan="7">Understand FDM, FEM and FVM and their differences.</td></tr>
<tr><td>CO4</td><td colspan="7">Understand different types of grid system.</td></tr>
<tr><td>CO5</td><td colspan="7">Understand different computing techniques.</td></tr>
<tr><td>UNIT I</td><td colspan="5"></td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Introduction: Basics of Computational Fluid Dynamics (CFD) – One dimensional computation: Finite difference methods (FDM) – Finite element method (FEM) – Finite volume method (FVM) – boundary conditions for FDM, FEM, and FVM. Governing equations: Classification of partial differential equations (PDE) – Navier-Stokes system of equations – boundary conditions</td><td>CO1</td></tr>
<tr><td>UNIT II</td><td colspan="5"></td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">FDM: Finite difference methods – Derivation of Finite Difference equation – Simple method – General method Higher order derivatives – Multi Dimensional Finite Difference Formulas – Mixes derivatives – Solution methods–Incompressible viscous flows - Artificial compressibility method – Pressure correction method. – Compressible viscous flows - Euler equations and Potential equations.</td><td>CO2</td></tr>
<tr><td>UNIT III</td><td colspan="5"></td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">FEM: Finite element methods – Formulation – Finite element interpolation functions – Linear problems – Non-linear problems – Incompressible viscous flows – Compressible viscous flows – Finite volume methods through finite difference methods – Formulations of finite volume equations: Burgers' equations – Incompressible and compressible flows.</td><td>CO3</td></tr>
<tr><td>UNIT IV</td><td colspan="5"></td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Grid generation: Structured grid generation: Algebraic methods – PDE mapping methods – Surface grid generation – Multi block structured grid generation. Unstructured grid generation: Delaunay-Voronoi methods (DVM) – Advancing front methods (AFM) – Combined DVM and AFM – Three dimensional applications. Adaptive methods: Structured and unstructured adaptive methods</td><td>CO4</td></tr>
<tr><td>UNIT V</td><td colspan="5"></td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Specialized Techniques: Computing techniques: Domain decomposition methods – Multigrid methods – Parallel processing. Applications of CFD: Turbulence – combustion – acoustics – Heat transfer – Multiphase flows – Electromagnetic flows.</td><td>CO5</td></tr>
<tr><td colspan="2">Lecture Periods: 45</td><td colspan="2">Tutorial Periods: -</td><td colspan="2">Practical Periods: -</td><td colspan="3">Total Periods: 45</td></tr>
</table>

Reference Books
1. Hoffmann, K. A., Computational Fluid Dynamics for Engineers, Engineering Education system, Wichita, Kansas, USA, 1993. 2. Fletcher, C. A., Computational Techniques for Fluid dynamics, Vol. 1: Fundamental and general techniques, Spring-Verlag, Berlin, 1998. 3. Wendt, J. F. (Ed.), Computational Fluid Dynamics – An Introduction, Springer Verlag, 1992. 4. Chung, T. J., Computational Fluid Dynamics, Cambridge University Press, 2003.

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	2	-	-
CO2	3	1	3	2	-	-
CO3	3	1	3	2	-	-
CO4	3	1	3	2	-	-
CO5	3	1	3	2	-	-

3 – High; **2** – Medium; **1** – Low

Department: **Mechanical Engineering**		Programme: **M.Tech (Energy Technology)**						
Semester: **Second**		Course Category Code: **PCC**			Semester Exam Type: **TY**			
Course Code	Course Name	Periods / Week			Credit	Maximum Marks		
		L	T	P		CA	SE	TM
ME257	**Modelling and Simulation of Energy Systems**	**3**	**-**	**-**	**3**	**40**	**60**	**100**
Prerequisite								

Course Outcome	**CO1**	Students will acquire knowledge on concepts of Modeling and its application in Energy Systems
	CO2	Students can do mathematical modeling of thermal systems
	CO3	Students will understand to simulate thermal systems for performance and alternatives
	CO4	Knowledge on concepts of optimization will be acquired
	CO5	Students will be able to use different conventional and specialized optimization methods for estimation of energy systems

UNIT I	**Periods** : **9**
Modeling: Energy systems – characteristics – workable system – optimum system – formulation of design problem - mathematical modeling – modelling of counter flow heat exchanger, evaporator, condenser, effectiveness-NTU methods, piping and pumping systems, turbo machines performance.	**CO1**
UNIT II	**Periods** : **9**
Modelling by curve fitting Development of modeling equations from curve fitting – exact fit and its types, polynomial interpolation, Lagrangian interpolation, Newton’s divided difference method – Best fit and its types - linear and non-linear regression - application in heat conduction, heat sinks of electronic circuits, modelling and evaluation of thermodynamic properties.	**CO2**
UNIT III	**Periods** : **9**
Simulation: Description- Uses of simulation – classes of simulation - Information flow diagrams – sequential and simultaneous calculations – techniques for system simulation - successive substitution method – Newton Raphson method, single and multiple unknowns – Matrix inversion method - Gauss-Seidel method – convergence in these methods - simulation of performance of compressors, blowers, fans, pumps, turbines.	**CO3**
UNIT IV	**Periods** : **9**
Optimization: Problem formulation and its representation objective functions - Lagrange multipliers – unconstrained optimization – constrained optimization – inequality constraints – calculus methods	**CO4**
UNIT V	**Periods** : **9**
Optimization: Search methods: Single variable, multivariable unconstrained lattice search, univariate search, steepest ascent –multivariable constrained, penalty functions, search along a constraint -Linear programming – Simplex method –application to material balances - Dynamic programming – characteristics – Genetic algorithms.	**CO5**

Lecture Periods: 45	**Tutorial Periods: -**	**Practical Periods: -**	**Total Periods: 45**

Reference Books

1. Hodge, B. K., Analysis and Design of Energy Systems, Prentice Hall Inc., 1990.
2. Press, W. H., et al., Numerical Recipes in Fortran – 2/e, Cambridge University Press, 1996.
3. Stoecker, W. F., Design of Thermal Systems, Tata McGraw Hill Education Pvt. Ltd., 2011.
4. C. Balaji, Thermal system Design and Optimization, Ane Books Pvt. Ltd., 2011.
5. YogeshJaluria, Design and Optimization of Thermal Systems , McGraw Hill, 2004.

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	3	1	-
CO2	3	1	3	3	1	-
CO3	3	1	3	3	1	-
CO4	3	1	3	3	1	-
CO5	3	1	3	3	1	-

3 – High; **2** – Medium; **1** – Low

<table>
<tr><td colspan="4">Department: Mechanical Engineering</td><td colspan="7">Programme: M.Tech.(Energy Technology)</td></tr>
<tr><td colspan="4">Semester: Second</td><td colspan="4">Course Category Code: PCC</td><td colspan="3">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td colspan="3" rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>ME258</td><td colspan="3">Optimization Techniques</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="10">NIL</td></tr>
<tr><td rowspan="5">Course Outcome</td><td>CO1</td><td colspan="9">Understand the essential features and scope of optimization techniques - Learn properties of objective function and formalization of optimization problem.</td></tr>
<tr><td>CO2</td><td colspan="9">Solve the Multi variable unconstraint optimization problems and its applications.</td></tr>
<tr><td>CO3</td><td colspan="9">Solve the Multi variable constraint optimization problems and its applications.</td></tr>
<tr><td>CO4</td><td colspan="9">Learn to solve Multi objective optimization problems - Apply in real life situations.</td></tr>
<tr><td>CO5</td><td colspan="9">Understand Genetic algorithms and its applications.</td></tr>
<tr><td>UNIT I</td><td colspan="8"></td><td colspan="2">Periods: 9</td></tr>
<tr><td colspan="10">Introduction – Principles of optimization, Formulation of objective function, design constraints-classification of optimization problems - Single variable unconstraint optimization – Boundary phase method- Fibonacci search method- Golden section search method.</td><td>CO1</td></tr>
<tr><td>UNIT II</td><td colspan="8"></td><td colspan="2">Periods: 9</td></tr>
<tr><td colspan="10">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.</td><td>CO2</td></tr>
<tr><td>UNIT III</td><td colspan="8"></td><td colspan="2">Periods: 9</td></tr>
<tr><td colspan="10">Multi variable constraint optimization: Lagrange's multipliers - Kuhn-Tucker conditions – Penalty function method – Frank-Wolfe method – Generalized projection method.</td><td>CO3</td></tr>
<tr><td>UNIT IV</td><td colspan="8"></td><td colspan="2">Periods: 9</td></tr>
<tr><td colspan="10">Multi objective optimization: Conjugate gradient method - reduced Conjugate gradient method – Newton – Raphson method. Integer Programming: Introduction – formulation – Geometry cutting plane algorithm – Zero or one algorithm, branch and bound method.</td><td>CO4</td></tr>
<tr><td>UNIT V</td><td colspan="8"></td><td colspan="2">Periods: 9</td></tr>
<tr><td colspan="10">Non-Traditional Optimization Algorithms: Genetics Algorithm-Working Principles, Similarities and Differences between Genetic Algorithm & Traditional Methods. Simulated Annealing-Working Principle-Simple Problems.</td><td>CO5</td></tr>
<tr><td colspan="2">Lecture Periods: 45</td><td colspan="3">Tutorial Periods: -</td><td colspan="3">Practical Periods: -</td><td colspan="3">Total Periods: 45</td></tr>
<tr><td colspan="11"><u>Reference Books</u></td></tr>
<tr><td colspan="11">1. Deb, K., Optimization for engineering design, Prentice Hall of India, 2005.
2. Rao, S.S., Optimization theory and applications, Wiley Eastern, 1984.
3. Davis, L., Handbook of genetic algorithms, Van Nostrand Reinhold, 1991.
4. Linear and Nonlinear Optimization, I. Griva, S. Nash, and A. Sofer, 2nd Edition, Society for Industrial and Applied Mathematics, 2009.
5. Optimization Techniques theory and practice by M.C.Joshi, K.M.Moudgalya, Narosa Publications, 2013.</td></tr>
</table>

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	3	1	-
CO2	3	1	3	3	1	-
CO3	3	1	3	3	1	-
CO4	3	1	3	3	1	-
CO5	3	1	3	3	1	-

3 – High; **2** – Medium; **1** – Low

<table>
<tr><td colspan="2">Department: Mechanical Engineering</td><td colspan="7">Programme: M.Tech.(Energy Technology)</td></tr>
<tr><td colspan="2">Semester: Second</td><td colspan="4">Course Category Code:PCC</td><td colspan="3">Semester Exam Type: LB</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>ME259</td><td>Computational Techniques Laboratory</td><td>-</td><td>-</td><td>4</td><td>2</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="8">NIL</td></tr>
<tr><td rowspan="3">Course Outcome</td><td>CO1</td><td colspan="7">Proficient programming in the FORTRAN language and write programs for implementing numerical algorithms</td></tr>
<tr><td>CO2</td><td colspan="7">To understand that FORTRAN is most useful for applications that are computational bound’</td></tr>
<tr><td>CO3</td><td colspan="7">Understanding solution accuracy, validation, verification and benchmarking</td></tr>
<tr><td colspan="9">List of Experiments :</td></tr>
<tr><td colspan="8">1. Solution to linear algebraic equations using Gauss-Seidel method.
2. Solution to linear algebraic equations using Conjugate Gradient method.
3. Solution to linear algebraic equations using GMRES method.
4. Solution to linear algebraic equations using LU decomposition method.</td><td>CO1</td></tr>
<tr><td colspan="8">5. Solution to nonlinear algebraic equations using Newton method.
6. Determining Eigen value and Eigen vector for a system of equations.
7. Finding roots of an equation using Newton-Raphson method.
8. Solution to ODEs using Runge-Kutta method</td><td>CO2</td></tr>
<tr><td colspan="8">9. Solution to ODEs through Finite Element method.
10. Solution to Poisson’s equation with Dirichlet and Convective boundary conditions.
11. Solution to 2D transient conduction equation using implicit method.
12. Solution to one dimensional wave equation.
13. Solution to 2D/3D problems using Fluent, Elmer, OpenFOAM etc.</td><td>CO3</td></tr>
<tr><td colspan="2">Lecture Periods: -</td><td colspan="3">Tutorial Periods: -</td><td colspan="2">Practical Periods: 60</td><td colspan="2">Total Periods: 60</td></tr>
</table>

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	3	-	-
CO2	3	-	3	1	3	
CO3	3	-	3	1	3	

3 – High; **2** – Medium; **1** – Low

<table>
<tr><td colspan="2">Department: Mechanical Engineering</td><td colspan="7">Programme: M.Tech.(Energy Technology)</td></tr>
<tr><td colspan="2">Semester: Second</td><td colspan="3">Course Category Code:PAC</td><td colspan="4">Semester Exam Type: LB</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>ME260</td><td>Mini Project and Seminar</td><td>-</td><td>-</td><td>4</td><td>2</td><td>100</td><td>-</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="8">NIL</td></tr>
<tr><td rowspan="4">Course outcome</td><td>CO1</td><td colspan="7">Students can make use of the opportunity to work in industry and get exposure</td></tr>
<tr><td>CO2</td><td colspan="7">Try to solve the practical problem in industry by using analytical and computational tools.</td></tr>
<tr><td>CO3</td><td colspan="7">To understand the concept and write a report/ research article.</td></tr>
<tr><td>CO4</td><td colspan="7">To improve the communication skill as well as presentation and explain their work technically</td></tr>
<tr><td colspan="9">Course content
Students can identify small problems facing in industry related to energy as mini project. It can be related to energy auditing, waste heat recovery, improvement of cycle efficiency, new material for energy, heat transfer analyses by using software tool etc. This mini project work is evaluated by panel of examiners assigned by HOD</td></tr>
<tr><td colspan="2">Lecture Periods: -</td><td colspan="2">Tutorial Periods:</td><td colspan="2">Practical Periods: 60</td><td colspan="3">Total Periods: 60</td></tr>
</table>

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	3	-	2
CO2	3	3	3	3	-	2
CO3	3	3	3	-	-	-
CO4	3	3	3	-	-	-

3 – High; **2** – Medium; **1** – Low

Department: **Mechanical Engineering**		Programme: **M.Tech. (Energy Technology)**						
Semester: **Third**		Course Category Code: **PAC**			Semester Exam Type: **TY**			
Course Code	Course Name	Periods / Week			Credit	Maximum Marks		
		L	T	P		CA	SE	TM
ME261	**Dissertation – Phase I**	**-**	**-**	**20**	**10**	**250**	**250**	**500**
Prerequisite	**NIL**							

Course Outcome		
Course Outcome	**CO1**	Students can make use of the opportunity to work in industry and get exposure or identify problem and conduct experiment within the department
	CO2	Understand a problem and try to adopt methodology to solve the problem successfully.
	CO3	Solve the practical problem by conducting experiments and using analytical or computational software to get accuracy.
	CO4	Get the exposure with various standards, codes, testing methods, gains knowledge in design and experiment.
	CO5	Write a report/ research article for publication, improve communication and presentation skills and explain their work technically

Course content

The students individually select any topic approved by the Head of the Department under the supervision of a faculty member who is knowledgeable in that area of interest. The student can select a specific topic which is relevant to the area of conventional, non-conventional energy, environment, energy management and heat transfer etc., which is useful for current and the future needs of the country/society. Based on the topic student have to collect latest information, detailed review of literature and identified current problem facing in the particular topic. The topic may be theoretical, modelling and simulation, experimental, fabrication type or energy auditing. At the end of the semester, after completed the work to the satisfaction with supervisor and review committee, a detailed report should be submitted to the head of the department on clear definition of the identified problem, detailed literature review related to the area of work, methodology to be adopted and some initial work carried out. The students will be evaluated based on the report submitted and through a viva-voce examination by an internal and an external examiners

Lecture Periods:	Tutorial Periods: -	Practical Periods: 300	Total Periods: 300

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	3	1	1
CO2	3	3	3	3	1	1
CO3	3	3	3	3	1	1
CO4	3	3	3	3	1	1
CO5	3	3	3	3	-	-

3 – High; **2** – Medium; **1** – Low

<table>
<tr><td colspan="2">Department: Mechanical Engineering</td><td colspan="7">Programme: M.Tech.(Energy Technology)</td></tr>
<tr><td colspan="2">Semester: Fourth</td><td colspan="4">Course Category Code: PAC</td><td colspan="3">Semester Exam Type: LB</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>ME262</td><td>Dissertation – Phase II</td><td>-</td><td>-</td><td>32</td><td>16</td><td>250</td><td>250</td><td>500</td></tr>
<tr><td>Prerequisite</td><td colspan="8">NIL</td></tr>
<tr><td rowspan="5">Course Outcome</td><td>CO1</td><td colspan="7">Students can make use of the opportunity to work in industry and get exposure or identify problem and conduct experiment within the department</td></tr>
<tr><td>CO2</td><td colspan="7">Understand a problem and try to adopt methodology to solve the problem successfully.</td></tr>
<tr><td>CO3</td><td colspan="7">Solve the practical problem by conducting experiments and using analytical or computational software to get accuracy.</td></tr>
<tr><td>CO4</td><td colspan="7">Get the exposure with various standards, codes, testing methods, gains knowledge in design and experiment.</td></tr>
<tr><td>CO5</td><td colspan="7">Write a report/ research article for publication, improve communication and presentation skills and explain their work technically</td></tr>
<tr><td colspan="9">Course content</td></tr>
<tr><td colspan="9">The student should be continuing the phase I work on the selected topic as per the formulated methodology under the same supervisor. At the end of the semester, after completing the work to the satisfaction with the supervisor and project review committee, a detailed report should be prepared and submitted to the head of the department. The students will be evaluated based on the report submitted and the viva-voce examination by an internal and an external examiner.</td></tr>
<tr><td colspan="2">Lecture Periods:</td><td colspan="2">Tutorial Periods: -</td><td colspan="3">Practical Periods: - 480</td><td colspan="2">Total Periods: 480</td></tr>
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CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	3	1	1
CO2	3	3	3	3	1	1
CO3	3	3	3	3	1	1
CO4	3	3	3	3	1	1
CO5	3	3	3	3	-	-

3 – High; **2** – Medium; **1** – Low

<table>
<tr><td colspan="2">Department: Mechanical Engineering</td><td colspan="7">Programme: M.Tech. (Energy Technology)</td></tr>
<tr><td colspan="2">Semester: First</td><td colspan="3">Course Category Code: PSE1/PSE2</td><td colspan="4">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>MEZ01</td><td>Advanced Fluid Mechanics</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="8">NIL</td></tr>
<tr><td rowspan="5">Course Outcome</td><td>CO1</td><td colspan="7">Students can make use of the opportunity to work in industry and get exposure or identify problem and conduct experiment within the department</td></tr>
<tr><td>CO2</td><td colspan="7">Understand a problem and try to adopt methodology to solve the problem successfully.</td></tr>
<tr><td>CO3</td><td colspan="7">Solve the practical problem by conducting experiments and using analytical or computational software to get accuracy.</td></tr>
<tr><td>CO4</td><td colspan="7">Get the exposure with various standards, codes, testing methods, gains knowledge in design and experiment.</td></tr>
<tr><td>CO5</td><td colspan="7">Write a report/ research article for publication, improve communication and presentation skills and explain their work technically</td></tr>
<tr><td>UNIT I</td><td colspan="5"></td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Kinematics and Kinetics: Kinematics of fluid flow - introduction – regimes of fluid mechanics - Lagrangian and Eulerian approach – revision of concepts of different types of fluids, stream lines, path lines, velocity potentials, vorticity – substantial derivative – equations of continuity – Euler’s equation – Bernoulli’s equations for ideal fluid flow - flow past circular cylinder with and without circulation – flow past an aerofoil</td><td>CO1</td></tr>
<tr><td>UNIT II</td><td colspan="5"></td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Viscous fluid flow: Viscous flow - stress components in real fluids – stress analysis on fluid motions – Navier Stokes equation of motion – energy equation – properties of Navier Stokes equation – exact solution of Navier Stokes equation for flow between parallel plates – couette flow – flow through pipes – flow between two concentric rotating cylinders</td><td>CO2</td></tr>
<tr><td>UNIT III</td><td colspan="5"></td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Laminar flow: Laminar boundary layer - laminar boundary layer equation – similarity solution for steady two dimensional flow – approximate integral method – numerical solutions - boundary layer control.</td><td>CO3</td></tr>
<tr><td>UNIT IV</td><td colspan="5"></td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Turbulent flow:
Turbulence-introduction to onset of turbulence–physical and mathematical description of turbulence–Reynolds equation for turbulent motion– semi empirical theories of turbulence–turbulent flow through pipes–turbulent boundary layer equations-turbulent flow with zero pressure gradient on smooth flat plate and rough flat plate</td><td>CO4</td></tr>
<tr><td>UNIT V</td><td colspan="5"></td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Compressible fluid flow: Compressible flow - fundamental equation of flow of compressible viscous and inviscid fluid – plane couette flow – exact solution – steady flow through constant area pipe – laminar boundary layer equation in compressible flow – boundary layer with pressure gradient and with zero pressure gradient – application of moment integral equation to boundary layers – turbulent boundary layer equations in compressible flow – compressible turbulent flow past a flat plate.</td><td>CO5</td></tr>
<tr><td colspan="2">Lecture Periods: 45</td><td colspan="2">Tutorial Periods: -</td><td colspan="3">Practical Periods: -</td><td colspan="2">Total Periods: 45</td></tr>
</table>

Reference Books
1. Bansal, J. L., Viscous Fluid Dynamics, Oxford & IBH Publications Co., 1977. 2. Frederick, S. Sherman, Viscous Flow, McGraw Hill Book Co., 1991. 3. Schlichting, H. and Gersten, K., Boundary Layer Theory - 8/e, Springer, 2000. 4. Yuan, S. W., Foundations in Fluid Mechanics, Prentice Hall of India Pvt. Ltd., 1988.

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	-	3	3	-	-
CO2	3	-	3	3	-	-
CO3	3	-	3	3	-	-
CO4	3	-	3	3	-	-
CO5	3	-	3	3	-	-

3 – High; **2** – Medium; **1** – Low

<table>
<tr><td colspan="2">Department: Mechanical Engineering</td><td colspan="5">Programme: M.Tech.(Energy Technology)</td><td colspan="3"></td></tr>
<tr><td colspan="2">Semester: First</td><td colspan="4">Course Category Code:PSE1/PSE2</td><td colspan="3">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>MEZ02</td><td>Advanced Refrigeration and Cryogenics</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="8">NIL</td></tr>
<tr><td rowspan="5">Course Outcome</td><td>CO1</td><td colspan="7">Study vapour compression refrigeration system working principle and components of vapour compression refrigeration system.</td></tr>
<tr><td>CO2</td><td colspan="7">Study the concept of jet ejector refrigeration system and its working principle and their different types.</td></tr>
<tr><td>CO3</td><td colspan="7">Study Cryogenics and liquefaction systems and different methods to achieve cryogenic refrigeration.</td></tr>
<tr><td>CO4</td><td colspan="7">Study different types of cryogenic refrigerators.</td></tr>
<tr><td>CO5</td><td colspan="7">Study Cryogenic-fluid storage and transfer systems, instrumentation and applications</td></tr>
<tr><td>UNIT I</td><td colspan="5"></td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Vapour compression refrigeration systems Vapour-compression refrigeration system and cycle – analysis of vapour-compression refrigeration system: system simulation – reciprocating compressor – condenser performance – analysis of condenser unit subsystem –evaporator performance – simulation of complete refrigeration system – performance matching – multi-pressure refrigeration systems: industrial refrigeration systems – removal of flash gases – system with one evaporator and one compressor – system with one evaporator and two compressors – system with two evaporators and one compressor – system with two evaporators and two compressors – refrigeration system with liquid recirculation</td><td>CO1</td></tr>
<tr><td>UNIT II</td><td colspan="5"></td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Vapour absorption and ejector refrigeration systems Vapour absorption refrigeration system and cycle – refrigerant-absorbent pairs – actual vapour absorption cycle and its representation on temperature-concentration and enthalpy-composition diagrams – thermal analysis of vapour absorption system – Lithium Bromide-water system: double-effect, half-effect and triple-effect cycles –ammonia-water systems: double-effect, double-lift and two-stage triple-effect systems – GAX cycles: concept, analysis and design considerations – branched GAX cycle – GAX cycle hardware - combined vapour absorption and compression system – commercial absorption units: crystallization – capacity control. Vapour ejector refrigeration system: theory of ejector – refrigerants for ejector system – analysis of ejector refrigeration system.</td><td>CO2</td></tr>
<tr><td>UNIT III</td><td colspan="5"></td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Cryogenics and liquefaction systems Cryogenic fluids and materials: properties – production of low-temperatures: Joule-Thomson effect – adiabatic expansion – liquefaction systems – analysis of Linde system: pre-cooled and dual-pressure systems – analysis of Claude system: pre-cooled and dual-pressure systems – analysis of Kapitza system – analysis of Heylandt system – analysis of Collins system – analysis of Simon system – classical casecade system – mixed-refrigerant casecade system – critical components of liquefaction systems – heat exchangers – compressors – expanders – expansion valves.</td><td>CO3</td></tr>
<tr><td>UNIT IV</td><td colspan="5"></td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Cryogenic refrigerators-Cryogenic refrigeration systems: thermodynamic analysis – Joule-Thomson refrigeration systems – casecade Joule- Thomson refrigeration systems – expansion-engine refrigeration systems – cold-gas refrigeration systems – Philips refrigerator – Solvey refrigeration systems – A.D. Little refrigeration systems – Vuilleumier refrigerator – Ericsson and Postle refrigerators – pulse tube refrigerator – miniature refrigerators – ultra low-temperature refrigerators: He – He dilution refrigerator – Pomeranchuk cooling system – magnetic cooling systems</td><td>CO4</td></tr>
</table>

UNIT V		Periods : 9
Cryogenic-fluid storage and transfer systems, instrumentation and applications Cryogenic-fluid storage vessels – insulation methods – cryogenic-fluid transfer systems – industrial storage and transfer – cooled-down of storage and transfer systems – instrumentation for low-temperatures: temperature, pressure, flow-rate and liquid-level measurements – applications of cryogenic systems: superconductive devices –cryogenics in space technology – cryogenics in biology and medicine		**CO5**

Lecture Periods: 45	**Tutorial Periods: -**	**Practical Periods: -**	**Total Periods: 45**

Reference Books

1. Koelet, P. C., Industrial Refrigeration – Principles, Design and Applications, Macmillan,1992.
2. Barron, Randel F., Cryogenic Systems, Oxford University Press, 1985.
3. Klaus D. Timmerhaus and Thomas M. Flynn, Cryogenic Process Engineering, Plenum Press, 1989.
4. ASHRAE Equipment Handbook, the American Society of Heating, Refrigerating and Air-conditioning Engineers Inc., Atlanta, Georgia.
5. Arora, C. P., Refrigeration and Air-conditioning, Tata McGraw Hill Publishing Co. Ltd., 2000.
6. Desrosier, N. W., Technology of Food Preservation, AVT Publishing Co., 2001

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	-	2	3	1	1
CO2	3	-	2	3	1	1
CO3	3	-	2	3	1	1
CO4	3	-	2	3	1	1
CO5	3	-	2	3	1	1

3 – High; **2** – Medium; **1** – Low

Department: **Mechanical Engineering**		Programme: **M.Tech.(Energy Technology)**						
Semester: **First**		Course Category Code: **PSE1/PSE2**				Semester Exam Type: **TY**		
Course Code	Course Name	Periods / Week			Credit	Maximum Marks		
		L	T	P		CA	SE	TM
MEZ03	**Fuels and Combustion**	**3**	**-**	**-**	**3**	**40**	**60**	**100**
Prerequisite	**NIL**							

Course Outcomes	**CO1**	Acquire knowledge on different types of solid fuels, their properties, and methods of measuring properties
	CO2	Acquire knowledge on various liquid and gaseous fuels, their properties and methods of characterization
	CO3	Perform calculations for the determination of important combustion parameters
	CO4	Understand different types of combustion processes and chain reactions
	CO5	Understand theory of flame propagation and burners used in different applications

UNIT I	**Periods** : **9**
Solid fuels: biomass-wood and charcoal-bagasse-other agricultural wastes- Peat-lignite- sub bituminous and bituminous coal- semi anthracite and anthracite-composition, physical and chemical properties-proximate and elemental analysis- calculation of proximate composition and calorific value- Processing of coal: washing and storage	**CO1**
UNIT II	**Periods : 9**
Liquid fuels – Petroleum: composition, classification, processing and some important petroleum products. Properties and testing of petroleum and petroleum products: specific gravity, viscosity, distillation range, flash and fire point, cloud and pour point, smoke point, carbon residue, sulphur content, ash, calorific value- octane number, cetane number- aniline point. Liquid fuels from sources other than petroleum : coal tar and coal tar fuels-motor benzol Gaseous fuels: Introduction-types- composition and characteristics of:- natural gas, water gas, carbureted water gas-blast furnace gas- LPG	**CO2**
UNIT III	**Periods : 9**
Combustion stoichiometry: flue gas analysis from fuel analysis and air supply. Excess air calculation from flue gas analysis-dew point of flue gases. Combustion thermodynamics: heat of combustion, enthalpy of combustion system- equilibrium constants of combustion reactions - adiabatic flame temperature and its determination.	**CO3**
UNIT IV	**Periods : 9**
Combustion kinetics – types of combustion process: combustion with stationary flames, flameless combustion, slow combustion, combustion of solid fuels on grate. Mechanism of combustion reactions-chain reaction, thermal mechanism, hydrogen-oxygen, carbon-monoxide-oxygen, hydrocarbon-oxygen chain reactions	**CO4**
UNIT V	**Periods : 9**
Introduction to ignition – spontaneous ignition temperature- flame propagation – limits of inflammability- theories of laminar flame propagation – structure of flame-flame stability Combustion appliances: gas burners, oil burners -types and applications-coal burning equipment	**CO5**

Lecture Periods: 45	**Tutorial Periods: -**	**Practical Periods: -**	**Total Periods: 45**

Reference Books
1. Samir Sarkar, Fuels and Combustion, 3e, Universities Press (India) Pvt limited,2009 2. Roger A. Strehlow, Fundamentals of Combustion, Krieger Pub. Co., 1979. 2. Kenneth K. Kuo, Principles of Combustion, 2e, Wiley, 2005. 3. Stephen R. Turns, An Introduction to Combustion, 3e, Tata McGraw Hill Education (India) Pvt. Ltd., 2012.

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	-	3	3	3	-
CO2	3	-	3	3	3	-
CO3	3	-	3	3	1	-
CO4	3	-	3	3	1	-
CO5	3	-	3	3	-	-

3 – High; **2** – Medium; **1** – Low

<table>
<tr><td colspan="2">Department: Mechanical Engineering</td><td colspan="8">Programme: M. Tech. (Energy Technology)</td></tr>
<tr><td colspan="2">Semester: First</td><td colspan="4">Course Category Code:
PSE1/PSE2</td><td colspan="4">Semester Exam Type:
TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td rowspan="2">Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>MEZ04</td><td>Biomass Conversion Systems</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="8">Nil</td></tr>
<tr><td rowspan="5">Course Outcomes</td><td>CO1</td><td colspan="7">Learnt the use of biomass as a fuel and analysed the biomass properties.</td></tr>
<tr><td>CO2</td><td colspan="7">Learnt the biomass-to-thermal energy via combustion and also solved problems.</td></tr>
<tr><td>CO3</td><td colspan="7">Learnt the use of producer gas generated from biomass via gasification.</td></tr>
<tr><td>CO4</td><td colspan="7">Learnt the use of secondary fuels generated from biomass via pyrolysis, esterification.</td></tr>
<tr><td>CO5</td><td colspan="7">Learnt the bio-chemical routes for conversion of biomass to energy.</td></tr>
<tr><td>UNIT I</td><td colspan="7"></td><td>Periods : 9</td></tr>
<tr><td colspan="8">Biomass, definition, classification – availability, estimation of availability – biomass resources – consumption and surplus biomass – energy plantations – Biomass analysis: properties, proximate analysis, ultimate analysis, thermos-gravimetric analysis and summative analysis – briquetting – pelleting.</td><td>CO1</td></tr>
<tr><td>UNIT II</td><td colspan="7"></td><td>Periods : 9</td></tr>
<tr><td colspan="8">Biomass combustion – biomass stoves, improved chullahs, types, some exotic designs – fixed bed combustors, types, inclined grate combustors – fluidized bed combustors – design, construction and operation of all the above biomass combustors – case studies.</td><td>CO2</td></tr>
<tr><td>UNIT III</td><td colspan="7"></td><td>Periods : 9</td></tr>
<tr><td colspan="8">Biomass gasification, producer gas – fixed bed system, downdraft and updraft gasifiers – design, construction and operation – fluidized bed gasifiers – gasifier+burner arrangement for heating – gasifier+engine+genset arrangement for electricity – equilibrium and kinetic consideration in gasifier operation – case studies.</td><td>CO3</td></tr>
<tr><td>UNIT IV</td><td colspan="7"></td><td>Periods : 9</td></tr>
<tr><td colspan="8">Biomass pyrolysis, types – manufacture of charcoal, yields and application – manufacture of pyrolytic oils and gases, yields and applications. Torrefaction of biomass.Non-edible vegetable oils and its blends with diesel – esterification, methods, yields, catalysts – bio-diesel and its blends with diesel – use as engine fuel, combustion characteristics and performance of these fuels in engines, power output, efficiency and emissions – case studies.</td><td>CO4</td></tr>
<tr><td>UNIT V</td><td colspan="7"></td><td>Periods : 9</td></tr>
<tr><td colspan="8">Biological conversion of biomass, methods – methanol, ethanol production – fermentation – anaerobic digestion – biogas plants – types of digesters, some exotic designs, factors affecting biogas generation – biogas technology for cooling, lighting and shaft power production – biogas compression - case studies.</td><td>CO5</td></tr>
<tr><td colspan="2">Lecture Periods: 45</td><td colspan="3">Tutorial Periods: Nil</td><td colspan="3">Practical Periods: Nil</td><td>Total: 45</td></tr>
</table>

Reference Books

1. Khandelwal, K. C. and Mahdi, S. S., Biogas Technology - A Practical Hand Book - Vol. I & II, Tata McGraw Hill Publishing Co. Ltd., 1983.
2. ABETS, Department of Aerospace Engineering, Biomass to Energy, Indian Institute of Science, Bangalore, 2003.
3. Biomass – Thermo-chemical characterization, Indian Institute of Technology, Delhi, 1997.
4. WereKo-Brobby, C. Y. and E. B. Hagan, Biomass Conversion and Technology, John Wiley & Sons, 1996.

CO	PO1	PO2	PO3	PO4	PO5	PO6
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

3 – High; **2** – Medium; **1** – Low

<table>
<tr><td colspan="2">Department: Mechanical Engineering</td><td colspan="4">Programme: M.Tech.(Energy Technology)</td><td colspan="3"></td></tr>
<tr><td colspan="2">Semester: First</td><td colspan="4">Course Category Code: PSE1/PSE2</td><td colspan="3">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>MEZ05</td><td>Cogeneration Technology</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="8">Knowledge in basics of thermodynamics, thermal power plant cycles.</td></tr>
<tr><td rowspan="5">Course Outcome</td><td>CO1</td><td colspan="7">Describe the power generation scenario, the layout components of thermal power plant and analyze the improved Rankin cycle, Cogeneration cycle</td></tr>
<tr><td>CO2</td><td colspan="7">Thermodynamic basis of available energy, exergy and entropy. Performance and classifications</td></tr>
<tr><td>CO3</td><td colspan="7">Calculations of performance parameters of cogeneration plants</td></tr>
<tr><td>CO4</td><td colspan="7">Design study of cogeneration plants</td></tr>
<tr><td>CO5</td><td colspan="7">Realize the details of diesel power plant, gas power plant and analyze gas turbine power cycle. Describe the different power plant electrical instruments and basic principles of economics of power generation.</td></tr>
<tr><td>UNIT I</td><td colspan="6">Principles of cogeneration</td><td colspan="2">Periods : 9</td></tr>
<tr><td colspan="8">Need for Cogeneration – Principle and Concept of Cogeneration – Review on Thermodynamics of conventional power producing plants – Selecting cogeneration technologies and Technical Options for Cogeneration.</td><td>CO1</td></tr>
<tr><td>UNIT II</td><td colspan="6">Performance evaluation of cogeneration systems</td><td colspan="2">Periods : 9</td></tr>
<tr><td colspan="8">Thermodynamics of Cogeneration power plants – performance criteria and effect of irreversibility – Classification of Cogeneration Systems – Factors Influencing Cogeneration Choice</td><td>CO2</td></tr>
<tr><td>UNIT III</td><td colspan="6">Parametric study on cogeneration plants</td><td colspan="2">Periods : 9</td></tr>
<tr><td colspan="8">Comparative thermodynamic performance of cogeneration plants – Important Technical Parameters for Cogeneration, performance of cogeneration plants – Numerical examples – calculations of typical heat to power ratios and performance parameters</td><td>CO3</td></tr>
<tr><td>UNIT IV</td><td colspan="6">Design of cogeneration systems</td><td colspan="2">Periods : 9</td></tr>
<tr><td colspan="8">Design of Cogeneration plant for varying plant heat to power ratio – fuel savings from installation of cogeneration plant – Prime Movers for Cogeneration, Relative Merits of Cogeneration Systems</td><td>CO4</td></tr>
<tr><td>UNIT V</td><td colspan="6">Cogeneration applications</td><td colspan="2">Periods : 9</td></tr>
<tr><td colspan="8">Cogeneration alternatives: Gas turbine – Steam turbine – Diesel engine – Topping and bottoming cycles. Industry / utility cogeneration: thermodynamic evaluation, Techno economic evaluation, Environmental evaluation. Cogeneration in sugar and steel industry, Case Studies</td><td>CO5</td></tr>
<tr><td colspan="2">Lecture Periods: 45</td><td colspan="2">Tutorial Periods: -</td><td colspan="3">Practical Periods: -</td><td colspan="2">Total Periods: 45</td></tr>
<tr><td colspan="9"><u>Reference Books</u></td></tr>
<tr><td colspan="9">1. Spiewak, S. A., Cogeneration, Fairmont Press Inc., 1991.
2. Kehlhofer, R., Combined Cycle Gas and Steam Turbine Power Plants, The Fairmont Press Inc., 1991.
3. Horlock, J. H., Cogeneration Combined Heat and Power – Thermodynamics and Performance, Pergamon Press, 1986.
4. Sirchis, J., Combined Production of Heat and Power, Elsevier Applied Science, 1990.
3. Robert Noyes, Cogeneration of Steam and Electric Power, Noyes Data Corporation, 1986.</td></tr>
</table>

CO	PO1	PO2	PO3	PO4	PO5	PO6
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

3 – High; **2** – Medium; **1** – Low

Department: **Mechanical Engineering**			Programme: **M.Tech.(Energy Technology)**						
Semester: **First**			Course Category Code:**PSE1/PSE2**			Semester Exam Type: **TY**			
Course Code	Course Name		Periods / Week			Credit	Maximum Marks		
			L	T	P		CA	SE	TM
MEZ06	**Electric Vehicle and Autonomous Transport**		**3**	**-**	**-**	**3**	**40**	**60**	**100**
Prerequisite	**NIL**								
Course Outcome	**CO1**	Knowing Battery Vehicle benefits, such as Reduce traffic congestion, vehicular emissions, collisional incidents and the cost and time of Transport							
	CO2	Understanding of Electric Vehicle and HEV Technology.							
	CO3	Fuel supply storage Fuel cell Electric Vehicle vis a vis chemical battery operated Electric Vehicle							
	CO4	Improve transportation safety, Integration and Synergy of Simulation using Scientific Computing with Artificial Intelligence for Mathematical modeling, simulations, and control of Autonomous Transport							
	CO5	Scientific machine learning for Autonomous Transport of EVs, HEV and FCVs and Role of ML assisted computational modeling							

UNIT I		**Periods : 9**
Review of Conventional ICE, EV, Hybrid and Fuel Cell Vehicle Technologies, Environmental Impact, Vehicle Propulsion, Technology of Fuel Supply and Battery Energy Storage		**CO1**
UNIT II		**Periods : 9**
Electric Vehicle – Configuration, Performance, Tractive Effort, Energy Consumption, Electric Propulsion, HEVs – Plugin, Mild hybrid, Regenerative braking		**CO2**
UNIT III		**Periods : 9**
Fuel Cells – Principle of operation, Types characteristics, Fuel Cell Vehicle – design methodology, parametric design, power design		**CO3**
UNIT IV		**Periods : 9**
Autonomous ground vehicles - Components, Control Systems and Operation of AVs, Sensors, Automated Driving Levels - Autonomy types, Path planning, Communications, connected Autonomous Electric Vehicles		**CO4**
UNIT V		**Periods : 9**
Introduction to Scientific Machine Learning – ML assisted Multiscale Multiphysics Simulation, Machine Learning Framework for Autonomous Transport, machine learning algorithms, Machine Learning Interface to Self Driven Transport, Edge and High Performance Computing for Autonomous Transport		**CO5**

Lecture Periods: 45	**Tutorial Periods: -**	**Practical Periods: -**	**Total Periods: 45**

Reference Books

1.Mehradad Ehsani, Yimin Gao, Stefano Longo and Ali Emadi (2018), Modern Electric, Hybrid Electric, and Fuel Cell Vehicles – Fundamentals, Theory and Design, CRC Press, New York.

2.Umit Ozguner, TankutAcarman and Keith Redmill, (2011), Autonomous Ground Vehicles, Artech House, Boston.

3. Andreas C. Muller and Sarah Guido (2016), Introduction to Machine Learning with Python A Guide for Data Scientists, O'Reilly Media, Inc., Boston.

4. Wei Liu (2017), Hybrid Electric Vehicle System Modeling and Control, Wiley, New Jersey.

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	2	2	3	2
CO2	3	2	2	3	3	2
CO3	3	2	2	2	3	2
CO4	3	2	2	2	3	2
CO5	3	2	2	2	3	2

3 – High; **2** – Medium; **1** – Low

<table>
<tr><td colspan="3">Department: Mechanical Engineering</td><td colspan="6">Programme: **M.Tech.(Energy Technology)**</td></tr>
<tr><td colspan="3">Semester: **First**</td><td colspan="3">Course Category Code:
PSE1/PSE2</td><td colspan="3">Semester Exam Type:
TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2" colspan="2">Course Name</td><td colspan="3">Periods / Week</td><td rowspan="2">Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>**MEZ07**</td><td colspan="2">**Energy Conversion Systems**</td><td>**3**</td><td>**-**</td><td>**-**</td><td>**3**</td><td>**40**</td><td>**60**</td><td>**100**</td></tr>
<tr><td>Prerequisite</td><td colspan="9">Nil</td></tr>
<tr><td rowspan="5">**Course Outcomes**</td><td>**CO1**</td><td colspan="8">Learnt the available sources for energy generation and their feasibility.</td></tr>
<tr><td>**CO2**</td><td colspan="8">Analysed the methods for thermal energy generation and also solved problems.</td></tr>
<tr><td>**CO3**</td><td colspan="8">Learnt the methods for electrical energy generation from solar and wind.</td></tr>
<tr><td>**CO4**</td><td colspan="8">Learnt the methods for electrical energy generation from sea water and fuel cells.</td></tr>
<tr><td>**CO5**</td><td colspan="8">Learnt how to store different forms of energy.</td></tr>
<tr><td>**UNIT I**</td><td colspan="7">**Energy sources**</td><td colspan="2">**Periods** : **9**</td></tr>
<tr><td colspan="9">Energy classification – Principal sources of energy: non-renewablesources like fossil fuels, nuclear fuels and renewable sources like biomass, solar, wind – Energy conversion –prospecting, extraction, resource assessment and their peculiar characteristics.</td><td>**CO1**</td></tr>
<tr><td>**UNIT II**</td><td colspan="7">**Thermal energy generation**</td><td colspan="2">**Periods** : **9**</td></tr>
<tr><td colspan="9">Production of thermal energy using fossil fuels, nuclear fuels, biomass,solar energy –Design principles of furnaces, kilns, ovens, combustors, fluid heaters, steam generators – problems. Applications of these devices.</td><td>**CO2**</td></tr>
<tr><td>**UNIT III**</td><td colspan="7">**Electrical energy generation from renewables – Part I**</td><td colspan="2">**Periods** : **9**</td></tr>
<tr><td colspan="9">Production of electrical energy fromsolar PV plants, wind turbines – principles, types of systems, governing factors, sites and economics for each of these types – Case studies.</td><td>**CO3**</td></tr>
<tr><td>**UNIT IV**</td><td colspan="7">**Electrical energy generation from renewables – Part II**</td><td colspan="2">**Periods** : **9**</td></tr>
<tr><td colspan="9">Production of electrical energy from waves, tides and ocean thermal – principles, issues and scope for development.Magneto Hydro Dynamic conversion – introduction – MHD plasma – analysis of MHD generators. Combined Cycle Power Plants.Fuel cells –general characteristics – types of fuel cells – fuel cell power plants.</td><td>**CO4**</td></tr>
<tr><td>**UNIT V**</td><td colspan="7">**Energy storage**</td><td colspan="2">**Periods** : **9**</td></tr>
<tr><td colspan="9">Energy storage requirements and methods – storage of thermal energy, PCM – storage of mechanical energy, types of devices – storage of electrical energy, batteries and their types – storage of chemical energy.</td><td>**CO5**</td></tr>
<tr><td colspan="2">**Lecture Periods: 45**</td><td colspan="3">**Tutorial Periods: Nil**</td><td colspan="3">**Practical Periods: Nil**</td><td colspan="2">**Total: 45**</td></tr>
<tr><td colspan="10">**<u>Reference Books</u>**
1. Angrist, S. W., - Direct Energy Conversion, Allyn and Bacon, Boston, 1982.
2. Green, M. A., - Solar Cells, Prentice Hall Inc., Englewood Cliffs, 1982.
3. Appleby, A. J., - Fuel Cell Hand Book, Van Nostrand Reinhold Co., New York, 1989.
4. Angrist, S. W., - Direct Energy Conversion, Allyn and Bacon, Boston, 1982.
5. Green, M. A., - Solar Cells, Prentice Hall Inc., Englewood Cliffs, 1982.</td></tr>
</table>

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	-	1	1	2	2
CO2	3	-	1	1	2	2
CO3	3	-	1	1	2	2
CO4	3	-	1	1	2	2
CO5	3	-	1	1	2	2

3 – High; **2** – Medium; **1** – Low

Department: **Mechanical Engineering**		Programme: **M.Tech.(Energy Technology)**	
Semester: **First**		Course Category Code: P**SE1/PSE2**	Semester Exam Type: **TY**

Course Code	Course Name	Periods / Week			Credit	Maximum Marks		
		L	T	P		CA	SE	TM
MEZ08	**Alternative fuels and their applications in combustion systems**	**3**	**-**	**-**	**3**	**40**	**60**	**100**
Prerequisite	**NIL**							

Course Outcome	**CO1**	Acquire knowledge on different types of alternative fuels and their properties for using in SI and CI engines
	CO2	Acquire knowledge on the methods of using various alternative fuels in SI engines and ability to compare the engine performance between baseline fuel and alternative fuel
	CO3	Acquire knowledge on the methods of using various alternative fuels in CI engines and ability to compare the engine performance between baseline fuel and alternative fuel
	CO4	Understand the effect using vegetable/biodiesel /bio-oil in CI engine and the effect on engine performance
	CO5	Understand the application of alternative fuels in marine, aviation, locomotive engines and thermal power plant with suitable case studies

UNIT I	**Periods : 9**
Review of desirable characteristics of fuels for SI and CI engines- Comparison of properties of alternative fuels with gasoline and diesel fuel. Bio-fuels: Biogas, methanol, ethanol, butanol, straight vegetable oil, biodiesel. Gaseous alternative fuels: Hydrogen- Liquefied Hydrogen, Compressed Natural Gas, Liquefied Natural Gas, Adsorbed Natural Gas, Liquefied Petroleum Gas, Landfill Gas. Synthetic alternative fuels: HCNG and Hythane, di-methyl ether, producer Gas , Fischer Tropsch diesel, eco-friendly plastic fuel, biomass pyrolysis oil and tyre pyrolysis oil	**CO1**
UNIT II	**Periods : 9**
Utilization of alternative fuels in SI engines-Alcohol, M85,E85 and gashol, hydrogen-natural gas– LPG- biogas-producer gas – Fuel\Engine modifications-conversion kits-Fuel induction systems - Differences in combustion, performance and emissions between alternative fuels and gasoline – case studies	**CO2**
UNIT III	**Periods : 9**
Utilization of alternative fuels in CI engines- alcohol, hydrogen-CNG –LPG- biogas-producer gas- Fuel\Engine modifications-Fuel induction systems- fumigation – dual fuel injection – Surface ignition - spark ignition- Differences in combustion, performance and emission between the alternative fuels and gasoline – case studies	**CO3**
UNIT IV	**Periods : 9**
Utilization of vegetable oil, its derivatives and bio-oil in CI engines. Conversion of vegetable oil into biodiesel- Biodiesel blends - Effect on engine performance and durability–Effect of biodiesel addition on emissions and combustion characteristics. Effect of injection pressure, injection timing and exhaust gas recirculation with biodiesel blends-case studies-utilization of bio-oil	**CO4**
UNIT V	**Periods : 9**
Potential alternative fuels for aircrafts, marine engines, locomotives and thermal power plants- Fuel quality requirements –biodiesel, alcohols, natural gas etc.- Engine performance and emissions -Case studies	CO5

Lecture Periods: 45	**Tutorial Periods: -**	**Practical Periods: -**	**Total Periods: 45**

Reference Books

1. S. S. Thipse, Alternative Fuels: Concepts, Technologies and Developments, Jaico Publishing House, 1st Edition 2010
2. M.K. Gajendra Babu, K.A. Subramanian, Alternative Transportation Fuels: Utilisation in Combustion Engines, 1st Edition, CRC Press, 2013
3. Gupta, H. N., Fundamentals of internal combustion engines, Prentice Hall India, 2006.
4. Mittal K.M., Biogas System Principles and application, New Age International (P) Ltd, Publishers, 1996.
5. Richard L. Bechtold, Alternative fuels guide book, SAE International, Wattendale, 1997
6. Ganesan. V., Internal Combustion Engines, Tata McGraw Hill Publishing company Ltd, New Delhi, 2003
7. Ramalingam, K.K., Internal Combustion Engines Theory and practice, Scitech Publications (India) Pvt, Ltd.,2010.

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	-	2	3	3	2
CO2	3	-	2	3	3	2
CO3	3	-	2	3	1	2
CO4	3	-	2	3	1	2
CO5	3	-	2	3	2	2

3 – High; **2** – Medium; **1** – Low

Department:**Mechanical Engineering**		Programme: **M.Tech.(Energy Technology)**							
Semester: **Second**		Course Category Code:**PSE3/PSE4**				Semester Exam Type: **TY**			
Course Code	Course Name	Periods / Week			Credit	Maximum Marks			
		L	T	P		CA	SE	TM	
MEZ09	**Hydrogen Energy and Fuel Cells**	**3**	**-**	**-**	**3**	**40**	**60**	**100**	
Prerequisite	**NIL**								
Course Outcome	**CO1**	Introduce hydrogen energy, its properties and production methods.							
	CO2	Study different methods of Hydrogen Energy Storage, Transportation and Applications.							
	CO3	Study handling Safety measures and environmental aspects of hydrogen.							
	CO4	Study fuel cell operation and types of fuel cell.							
	CO5	Study fuel cell applications and its economics.							

UNIT I		**Periods : 9**
Hydrogen Energy : Hydrogen as an energy source – Properties of hydrogen – Combustion methods and devices – Economics of hydrogen energy – Production of hydrogen: natural resource – biological source - electrolytic process – thermal decomposition – biochemical method – photochemical method – photo-catalytic method.		**CO1**
UNIT II		**Periods : 9**
Hydrogen Energy Storage, Transportation and Applications: Selection of storage: Gaseous, liquid – Method of storage: Gaseous hydrogen, cryogenic method, metal hydrides, arbonnano-tubes, sea as a source of deuterium – Transportation: methods of transport – cryo-cooled systems –Fuel cells – Applications of hydrogen energy in land and space vehicles – Hydrogen power technologies.		**CO2**
UNIT III		**Periods : 9**
Safety and environmental aspects of hydrogen :Hydrogen sensing and detection: hydrogen measuring principles – traditional sensing methods: thermal conductivity, gas chromatography, mass spectroscopy, laser gas analysis – solid-state sensing techniques –operation mechanisms of solid-state sensors – hydrogen sensors for industrial processes – sensors in hydrogen fuel applications – hydrogen safety: hydrogen hazards – hazards in hydrogen storage facilities – hazards in using hydrogen as fuel in transport sectors – hydrogen codes and standards: national codes – national templates – selected highlights of national templates – key issues: performance based versus prospective standards – coordination of international and domestic standards.		**CO3**
UNIT IV		**Periods : 9**
Fuel cell operation–low-to-medium temperature fuel cells: phosphoric acid fuel cell, alkaline fuel cell, direct borohydride fuel cell, proton-exchange membrane fuel cell, direct methanol fuel cell, miniature fuel cells – high temperature fuel cells: Molten carbonate fuel cell, direct carbon fuel cell, solid oxide fuel cell – fuel cell efficiencies.		**CO4**
UNIT V		**Periods : 9**
Fuel cell applications and economics :Applications of fuel cells – prognosis for fuel cells – fuel cells in dispersed-energy systems (Utility use) – Fuel cells in on-site Integrated energy systems and Industrial co-generation – Fuel cell commercial availability – market and cost analysis of fuel cell technology – environmental aspects and impact assessment.		**CO5**

Lecture Periods: 45	**Tutorial Periods: -**	**Practical Periods: -**	**Total Periods: 45**

Reference Books
1. Karl V. Kordesch, Dr. Günter R. Simader, Fuel Cells: and their Applications, Wiley Publications, 1996. 2. Ram B. Gupta, Hydrogen Fuel: Production, Transport and Storage, CRC Press, 2009. 3. Jamasb, T., Pollitt, M. G. and Nuttall, W. J., Future Electricity Technologies and Systems, CambridgeUniversity Press,2006 4. Ryan O'Hare, Suk-Won Cha, Whitney Colella, Fritz B.Prinz., Fuel Cell Fundamentals, John Wiley & SonsInc.,2ndEdition,2009.

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	-	3	2	1	1
CO2	3	-	3	2	3	3
CO3	3	-	3	2	3	3
CO4	3	-	3	2	-	-
CO5	3	-	3	2	-	-

3 – High; **2** – Medium; **1** – Low

<table>
<tr><td colspan="2">Department: Mechanical Engineering</td><td colspan="6">Programme: M.Tech.(Energy Technology)</td></tr>
<tr><td colspan="2">Semester: Second</td><td colspan="4">Course Category Code: PSE3/PSE4</td><td colspan="3">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>MEZ10</td><td>Micro-Nano scale fluid flow and heat transfer</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="8">Knowledge in fluid mechanics and heat transfer basics</td></tr>
</table>

Course Outcome		
	CO1	Design and function of Micro-Nano fluidic based technologies. Mathematic modelling and properties of fluid flow
	CO2	Fundamentals of compressible fluid flow its properties in Micro and Nano scale flows. Understand the principles of operation for microscale flow transport.
	CO3	Fundamentals of incompressible fluid flow its properties in Micro and Nano scale flows. Understand the principles of operation for microscale flow transport.
	CO4	Importance of surface tension, electro-kinetic effects, molecular diffusion, heat transfer in micro/nano scale phenomena and benefits and limitations of micro-nanofluidic systems
	CO5	Modeling and simulation methodology applied to study micro-nano scale phenomena.

UNIT I	**Introduction to micro-nano fluid flow**	**Periods : 9**
Introduction, Lab on a Chip, MEMS Technology - scaling issues in heat transfer and fluids, Derivation of governing equations of mass, momentum and energy, Fluid flow properties, Applications.		**CO1**
UNIT II	**Gas flow analysis**	**Periods : 9**
Gas flows - Elements of kinetic theory of gases, Transition and Free Molecular Flow Regime, Rarefied gasphenomena, Gas surface interactions - Tangential momentum accommodation coefficient, Burnett equations, solution in microchannel.		**CO2**
UNIT III	**Liquid flow analysis**	**Periods : 9**
Liquid flows - Introduction, Challenges in mixing at micro-scales, Electro-kinetic effects Analysis – EDL/Bulk flow interface velocity, governing equations of EOF – Complex geometry flows, Di-electrophoresis		**CO3**
UNIT IV	**Two-phase flow in micro-nano scale**	**Periods : 9**
Two-phase flows – Capillary effects, Surface Tension, Contact Angle, Marangoni effect, surface tension gradient,Gas bubbles, Two Phase Poiseuille Flow, Droplet and Digital Microfluidics – Hagen Poiseuille and Young Laplace pressure drops		**CO4**
UNIT V	**Heat transfer in micro channels and nano fluids**	**Periods : 9**
Heat Transfer - Forced convection with slip, Thermal effects at microscales, Nanofluidics and Molecular dynamics – MD Continuum coupling, Direct simulation Monte-Carlo, Limitations and Errors in DSMC, Boltzmann Equation - Lattice Boltzmann method, Meshless Numerical Method.		**CO5**

Lecture Periods: 45	**Tutorial Periods: -**	**Practical Periods: -**	**Total Periods: 45**

Reference Books

1. Nguyen, N. T., and Wereley, S. T., Fundamentals and Applications of Microfluidics, Artech House, Boston, 2006.
2. Gomez, F. A. (Ed.), Biological Applications of Microfluidics, Wiley, New Jersey, 2008.
3. Karniadakis, G., Beskok, A., and Aluru, N., Microflows and Nanoflows – Fundamentals and Simulation, Springer, New York, 2005.
4. Rogers, B., Pennathur, S., and Adams, J., Nanotechnology – Understanding Small Systems, CRC Press, New York, 2008.

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	-	2	1		
CO2	2	-	2	1	-	-
CO3	2	-	2	1	-	-
CO4	2	-	2	1	-	-
CO5	2	-	2	2	-	-

<table>
<tr><td colspan="3">Department: Mechanical Engineering</td><td colspan="5">Programme: M.Tech.(Energy Technology)</td></tr>
<tr><td colspan="3">Semester: Second</td><td colspan="4">Course Category Code:PSE3/PSE4</td><td colspan="3">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2" colspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>MEZ11</td><td colspan="2">Energy Conservation and Management Systems</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td colspan="10">Prerequisite</td></tr>
<tr><td rowspan="5">Course Outcome</td><td>CO1</td><td colspan="8">Understand the fundamentals of energy conservation.</td></tr>
<tr><td>CO2</td><td colspan="8">Select methods of thermal energy conservation for improved performance and efficiency.</td></tr>
<tr><td>CO3</td><td colspan="8">Apply the principles of thermal engineering to improve the performance of thermal systems.</td></tr>
<tr><td>CO4</td><td colspan="8">Analyze the methods of energy conservation in pumps, fans, motors, compressed air systems, refrigeration & air conditioning systems andindustries.</td></tr>
<tr><td>CO5</td><td colspan="8">Understand the Concept of energy management and Carry out energy audit of an industry/Organization.</td></tr>
<tr><td colspan="9">UNIT I</td><td>Periods: 9</td></tr>
<tr><td colspan="9">Concept of energy conservation – Sankey diagram – thermodynamic limitations: first and second laws of thermodynamics of energy transfer – availability analysis of various thermodynamics processes/devices/cycles. Need for energy conservation in domestic, transportation, agricultural and industrial sectors – Lighting and HVAC systems – simple case studies.</td><td>CO1</td></tr>
<tr><td colspan="9">UNIT II</td><td>Periods: 9</td></tr>
<tr><td colspan="9">Thermal energy conservation: combustion systems and processes – combustion efficiency – boiler performance –methodology of improving the boiler performance – steam turbine and distribution systems: energy conservation in turbines – necessity for maintenance of correct pressure, temperature and quality of steam – condensate recovery – recovery of flash steam – air and gas removal – thermal insulation.</td><td>CO2</td></tr>
<tr><td colspan="9">UNIT III</td><td>Periods: 9</td></tr>
<tr><td colspan="9">Heat exchange systems – recuperative and regenerative heat exchangers – compact heat exchangers – fluidized bed heat exchange systems – heat pumps – heat pipes – heat recovery from industrial processes. heat exchange networking – pinch analysis – target setting, problem table approach, composite curves – waste heat recovery and cogeneration schemes.</td><td>CO3</td></tr>
<tr><td colspan="9">UNIT IV</td><td>Periods: 9</td></tr>
<tr><td colspan="9">Energy conservation in industries - energy conservation in pumps, fans, compressed air systems, refrigeration & air conditioning systems, emergency DG sets, illumination, electrical motors – energy efficient motors and variable speed motors. Case studies for energy conservation in various industries such as cement, iron and steel, glass, fertilizer, food processing, refinery etc.</td><td>CO4</td></tr>
<tr><td colspan="9">UNIT V</td><td>Periods: 9</td></tr>
<tr><td colspan="9">Concept of energy management – Energy demand and supply – Economic analysis of energy options – Duties of energy managers. Energy auditing: definition, necessity and types. Understanding energy costs – bench marking –energy performance – matching energy use to requirement – maximizing system efficiencies – optimizing the input energy requirements. Fuels and energy: supplementing and substitution – energy audit instruments – energy economics: discount rate, payback period, internal rate of return, life cycle costing – energy conservation systems analysis for safety, health and pollution.</td><td>CO5</td></tr>
<tr><td colspan="3">Lecture Periods: 45</td><td colspan="2">Tutorial Periods: -</td><td colspan="3">Practical Periods: -</td><td colspan="2">Total Periods: 45</td></tr>
</table>

Reference Books
1. O’ Callaghan, P., Energy Management, McGraw Hill Book Company, 1993.
2. Gottschalk, C. M., Industrial Energy Conservation, John Wiley & Sons, 1996.
3. Patrick, D. and Fardo, S. W., Energy conservation and management, Prentice-Hall Inc., 1990.
4. Wayn C. Turner, Energy management handbook, The Fairmount press, 1998.

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	-	2	1	1	1
CO2	3	-	2	1	1	1
CO3	3	-	2	2	1	1
CO4	3	-	2	2	1	1
CO5	2	-	2	2	1	1

Department: **Mechanical Engineering**		Programme: **M.Tech. (Energy Technology)**						
Semester: Second		Course Category Code: **PPSE3/PSE4**				Semester Exam Type: **TY**		
Course Code	Course Name	Periods / Week			Credit	Maximum Marks		
		L	T	P		CA	SE	TM
MEZ12	**Nuclear Power Engineering**	**3**	**-**	**-**	**3**	**40**	**60**	**100**
Prerequisite	Strong understanding of molecular physics and thermal engineering							

Course Outcome		
	CO1	Understand the basic concepts related to nuclear energy
	CO2	Get insight about nuclear reactors and its various functionality including the waste disposal and management.
	CO3	Further insights into the theoretical working and applications of the nuclear reaction.
	CO4	To comprehend the analytical working of the reactor and its design aspects
	CO5	To understand, evaluate and analyse the thermal energy from reactors.

UNIT I	**Periods**: 9
Nuclear energy-Radioactivity – nuclear reactions – binding energy – neutron interaction – cross sections – fission – power from fission – fission chain reactions – criticality – conversion and breeding – nuclear fuel performance	**CO1**
UNIT II	**Periods**: 9
Nuclear reactors and cycles Nuclear power reactors – nuclear fuel cycles – fuel enrichment – fuel assembly – fuel reprocessing –decommissioning of power plants – radioactive waste disposal and its management	**CO2**
UNIT III	**Periods**: 9
Theory of nuclear reaction Neutron flux – diffusion theory applications – Fick’s law – solution to diffusion equation for point source – plannar source and bare slab – diffusion length – energy loss in scattering collisions – moderators.	**CO3**
UNIT IV	**Periods**: 9
Reactor kinetics One group reactor equation – one group criticality equation – thermal reactors – criticality calculations –homogeneous and heterogeneous reactors – reactor kinetics and safety – prompt neutron life time – reactor with and without delayed neutrons – prompt criticality – control rods – principles of nuclear reactor safety.	**CO4**
UNIT V	**Periods**: 9
Thermal energy from reactors Heat generation in reactors – thermal constraints – heat transfer to coolants – thermal design of reactor.	**CO5**

Lecture Periods: 45	**Tutorial Periods: -**	**Practical Periods: -**	**Total Periods: 45**

Reference Books

1. Samuel Glasstone, Principle of Nuclear Reactor Engineering, Van Nostrand Reinhold Co., New York, 1963.
2. Culp, Archie W., Principles of Energy Conversion, McGraw Hill Book Co., 1991.
3. Lamarsh, J. R., Introduction to Nuclear Engineering, Addison-Wesley, New York, 1983.
4. Marshall, W., Nuclear Power Technology - Vol. I, II & III, Clarendon Press, Oxford, 1985.

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	-	2	2	2	2
CO2	3	-	2	2	3	3
CO3	3	-	3	3	1	1
CO4	3	-	3	3	1	1
CO5	3	-	2	3	1	1

3 – High; **2** – Medium; **1** – Low

<table>
<tr><td colspan="3">Department: Mechanical Engineering</td><td colspan="5">Programme: M.Tech. (Energy Technology)</td></tr>
<tr><td colspan="3">Semester: Second</td><td colspan="4">Course Category Code:PSE3/PSE4</td><td colspan="3">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2" colspan="2">Course Name</td><td colspan="3">Periods / Week</td><td rowspan="2">Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>MEZ13</td><td colspan="2">Power Plant Management & Economics</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td colspan="2">Prerequisite</td><td colspan="8">Nil</td></tr>
<tr><td rowspan="5">Course Outcomes</td><td>CO1</td><td colspan="8">Learnt the fundamental aspects of power plant economics and to solve problems.</td></tr>
<tr><td>CO2</td><td colspan="8">Studied the techniques for economical operation of power plants.</td></tr>
<tr><td>CO3</td><td colspan="8">Learnt the methods of electrical load management in power plants.</td></tr>
<tr><td>CO4</td><td colspan="8">Studied the operation and control of power plant.</td></tr>
<tr><td>CO5</td><td colspan="8">Learnt the managements in the various sectors of a power plant.</td></tr>
<tr><td>UNIT I</td><td colspan="8">Power plant economics</td><td>Periods : 9</td></tr>
<tr><td colspan="9">Power Plant Economics and Tariffs: Load curve, load duration curve, different factors related to plants and consumers, Cost of electrical energy, depreciation, generation cost, effect of load factor on unit cost. Fixed and operating cost of different plants, role of load diversity in power system economy. Objectives and forms of Tariff: Causes and effects of low power factor, advantages of power factor improvement, different methods for power factor improvements.</td><td>CO1</td></tr>
<tr><td>UNIT II</td><td colspan="8">Economic Operation of Power Systems</td><td>Periods : 9</td></tr>
<tr><td colspan="9">Characteristics of steam and hydro-plants, Constraints in operation, Economic load scheduling of thermal plants, Neglecting and considering transmission Losses, Penalty factor, losscoefficients, Incremental transmission loss.</td><td>CO2</td></tr>
<tr><td>UNIT III</td><td colspan="8">Load management</td><td>Periods : 9</td></tr>
<tr><td colspan="9">Demand Side Load Management: Concepts, Barriers, Planning and Implementation methods etc., management philosophy- leadership- work environment- delegation-organization – human resources – policies – common tasks – communications – finance – taxation/depreciation – legal aspects – quality controls – Insurance.</td><td>CO3</td></tr>
<tr><td>UNIT IV</td><td colspan="8">Plant operation and control</td><td>Periods : 9</td></tr>
<tr><td colspan="9">Organizational design of power plant – plant operation – quality control – maintenance schedule – log books –production records.</td><td>CO4</td></tr>
<tr><td>UNIT V</td><td colspan="8">Power plant management</td><td>Periods : 9</td></tr>
<tr><td colspan="9">Plant business units: strategic, operating and resource, management roadmaps and attributes – general/plant management – business management- accounting management – fuels, energy and emissions management –profit-centred maintenance management – engineering management – operations management – planning &scheduling management – human resources management – environmental management – health & safety management – quality management.</td><td>CO5</td></tr>
<tr><td colspan="3">Lecture Periods: 45</td><td colspan="3">Tutorial Periods: Nil</td><td colspan="3">Practical Periods: Nil</td><td>Total: 45</td></tr>
</table>

Reference Books

1.Stevenson, W. D., Elements of Power System Analysis, McGraw Hill, 1994.

2. Bernhardt G. A. Skrotzki, William A. Vopat, Power Station Engineering and Economy, Tata McGrawHill, 1993.

2. Soni Gupta and Bhatnagar, A text book on Power System Engineering, DhanpatRai& Co. 2004.

3. Murthy, P. S. R., Operation and control of Power System", BS Publications, Hyderabad, 2007.

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	-	1	-	-	-
CO2	3	-	1	-	-	-
CO3	3	-	1	-	-	-
CO4	3	-	1	-	1	1
CO5	3	-	1	-	1	1

3 – High; **2** – Medium; **1** – Low

Department: **Mechanical Engineering**			Programme: **M.Tech.(Energy Technology)**						
Semester: **Second**			Course Category Code: **PSE3/PSE4**				Semester Exam Type: **TY**		
Course Code	Course Name		Periods / Week			Credit	Maximum Marks		
			L	T	P		CA	SE	TM
MEZ14	**Thermal Turbo machines**		**3**	**-**	**-**	**3**	**40**	**60**	**100**
Prerequisite	**Knowledge in thermal engineering and fluid mechanics**								
Course Outcome	**CO1**	Fundamentals and working principles of turbo machines and its performances.							
	CO2	Theoretical and numerical Analysis of flow through prime movers.							
	CO3	Performance characteristics of prime movers and its applications							
	CO4	Fundamentals and working principles of compressors. Mathematical modelling and design of compressors for power and transportations.							
	CO5	Fundamentals and working principles of fans. Mathematical modelling and design of compressors for power and transportations.							

UNIT I	**Theory of turbo machines**	**Periods : 9**
Introduction to Thermal Turbo machines – Principle of operation – energy equation – classifications – work done, Losses and efficiencies – performance characteristics.		**CO1**
UNIT II	**Flow analysis**	**Periods : 9**
Flow through nozzles and diffusers – Steam turbines – impulse turbine and reaction turbines – velocity triangles –compounding – considerations in design of nuclear steam turbines – governing of steam turbines.		**CO2**
UNIT III	**Gas turbines**	**Periods : 9**
Gas turbine- classification – Thermodynamics of axial and radial flow gas turbines- Degree of Reaction-Design procedure for turbine stage - stage efficiency – Performance – Gas turbine cycle – simple cycle and cogeneration cycle – effect of operating variables on thermal efficiency – application of gas turbines: aircraft-surface vehicles electric power generation.		**CO3**
UNIT IV	**Compressors**	**Periods : 9**
Compressors – classification – Axial flow Compressor – Stage Velocity triangles – Enthalpy Entropy diagram – Flow through blade rows-stage losses and efficiency – Work done factor –Performance characteristics – Centrifugal Compressors – elements of a centrifugal compressor stage- – Stage Velocity triangles – Enthalpy-Entropy diagram – nature of impeller flow – slip factor – volute casing – stage losses and efficiency – Performance Characteristics.		**CO4**
UNIT V	**FANS**	**Periods : 9**
Axial fans – Principle of operation – types of axial fan stages – performance of axial fans – applications –Centrifugal fans – types – fan stage parameters – drum type and partial flow fans – losses and performance – pure air handling system in industrials applications		**CO5**

Lecture Periods: 45	**Tutorial Periods: -**	**Practical Periods: -**	**Total Periods: 45**

Reference Books

1. Cohen, H., G.F.C. Rogers and H.I.H. Saravanamuttoo, Gas Turbine Theory, 5th edition., Prentice Hall, 2001.
2. Kerten, W.J., Steam Turbine - Theory and Practice, CBS Publishing 1988.
3. Yahya, S.M., Turbines Compressors and Fans, Tata McGraw-Hill Company, 2002.
4. Shephard, D.G., Principles of Turbomachines, Macmillan Company, 1984

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	-	3	1	-	-
CO2	3	-	3	1	-	-
CO3	3	-	3	1	-	-
CO4	3	-	3	1	-	-
CO5	3	-	3	1	-	-

3 – High; **2** – Medium; **1** – Low

Department: **Mechanical Engineering**			Programme: **M.Tech. (Energy Technology)**						
Semester: **Second**			Course Category Code: **PSE3/PSE4**				Semester Exam Type: **TY**		
Course Code	Course Name		Periods / Week			Credit	Maximum Marks		
			L	T	P		CA	SE	TM
MEZ15	**Solar Power Technology**		**3**	**-**	**-**	**3**	**40**	**60**	**100**
Prerequisite	**Understanding in thermal engineering and theory behind photo voltaics**								
Course Outcome	**CO1**	To gain knowledge about solar radiation and its related concepts							
	CO2	Understand solar thermal conversion and the various concepts surrounding thermal devices							
	CO3	To get insights into the working of various solar thermal storage including phase change materials, its performance and analysis							
	CO4	To understand the basics of photovoltaics and to design, fabricate and analyse the performance of various PV cells and its applications							
	CO5	To understand, evaluate and analyse the performance of the various solar energy devices							

UNIT I	**Periods: 9**
Solar radiation: Solar energy, geometry, solar radiation – availability, measurement and estimation – solar tracking – Isotropic and anisotropic models – empirical relations	**CO1**
UNIT II	**Periods: 9**
Solar thermal conversion: Solar thermal devices – liquid flat plate collectors, materials, selective surfaces, cover plates – thermal analysis of collector – solar air heaters – construction, performance and analysis. Concentrating collectors: types – heliostats — solar ponds.	**CO2**
UNIT III	**Periods: 9**
Solar thermal storage: Solar thermal energy storage – sensible heat storage - latent heat storage- Thermo chemical storage - water, packed bed storages – storage in phase change materials, performance and analysis	**CO3**
UNIT IV	**Periods: 9**
Solar photovoltaic: Solar cells – photovoltaic principle – materials for photovoltaic cells – design and fabrication of photovoltaic cells – performance analysis of photovoltaic cells – thermoelectric generator solar cells – photochemical solar cells – solar photovoltaic power plants – terrestrial and space applications	**CO4**
UNIT V	**Periods: 9**
Applications of solar energy: Solar lighting – solar cooling – heat pump – solar drying – solar cooking - solar passive buildings – solar power plants – performance and analysis – case studies – installation methods	**CO5**

Lecture Periods: 45	**Tutorial Periods: -**	**Practical Periods: -**	**Total Periods: 45**

Reference Books

1. Cohen, H., G.F.C. Rogers and H.I.H. Saravanamuttoo, Gas Turbine Theory, 5th edition., Prentice Hall, 2001.
2. Kerten, W.J., Steam Turbine - Theory and Practice, CBS Publishing 1988.
3. Sukhatme, S. P., Solar Energy- Principles of Thermal collection and Storage, Tata McGraw Hill PublishingCo. Ltd., 1994.
4. Bansal, N. K., Manfred Kleeman and Michael Meliss, Renewable Energy Sources and ConversionTechnology, Tata McGraw Hill Publishing Co. Ltd., 1990.
5. Jiu Sheng Hsieh, Solar Energy Engineering, Prentice Hall Inc., 1991.

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	-	2	1	3	1
CO2	3	-	3	1	3	1
CO3	3	-	3	1	3	1
CO4	3	-	3	1	3	1
CO5	3	-	3	1	3	1

3 – High; **2** – Medium; **1** – Low

Department: **Mechanical Engineering**		Programme: **M.Tech.(Energy Tecnology)**						
Semester: S**econd**		Course Category Code: **PSE3/PSE4**				Semester Exam Type: **TY**		
Course Code	Course Name	Periods / Week			Credit	Maximum Marks		
		L	T	P		CA	SE	TM
MEZ16	**Ultra Supercritical Power Plants and Materials**	**3**	**-**	**-**	**3**	**40**	**60**	**100**
Prerequisite	**NIL**							

Course Outcome		
Course Outcome	**CO1**	Ability to understand the various types of power plants and cycles
	CO2	Ability to understand safety and control the operating parameter in power plant
	CO3	Ability to select the proper materials for power plants components
	CO4	Ability to understand the concept of non- conventional technologies
	CO5	Ability to understand the various failures that occur in power plants

UNIT I	**Periods** : 9
Introduction of sub critical - supercritical - ultra supercritical power plants - parameters - working principle of supercritical boiler - Supercritical Pressure and temperature - drum type – once through type – supercritical Rankine cycles - increase the efficiency - Steam generator configuration – advantages – application	**CO1**
UNIT II	**Periods** : 9
Water walls arrangements - Steam water cycle chemistry controls – firing system – combustion control – steam temperature control - Feed water control – boiler side – turbine side – feed water treatment –draught control –soot blower – quality of steam control- safety measures	**CO2**
UNIT III	**Periods** : 9
Selection of super critical boiler materials – present trend - potential benefits -materials development -requirements of materials for high temperature applications - materials for boiler tubes and pipes- super heater and reheater tubes - Steam Piping and Headers -turbine materials - HP/IP Rotors	**CO3**
UNIT IV	**Periods** : 9
MHD power generation-principle - open and closed cycle's systems- thermoelectric power – generation -thermionic power generation – hydrogen energy – fuel cell – power generation using nano fluid – thermo electric devices	**CO4**
UNIT V	**Periods** : 9
Fire-side corrosion – steam -side oxidation – sulfidation -environmentally induced cracking -stress corrosion cracking -hydrogen embrittlement - corrosion fatigue - liquid metal embrittlement- caustic corrosion – hydrogen damage – erosion - coal ash corrosion - high temperature creep – water wall corrosion – boiler installation –Indian boilers act 1923 and regulation act 1950	**CO5**

Lecture Periods: 45	**Tutorial Periods: -**	**Practical Periods: -**	**Total Periods: 45**

<u>Reference Books</u>

1. M. M. El-wakil, Power Plant Technology, McGraw Hill Education (India) Private Limited, 2010
2. Flake C. Campbel, Elements of Metallurgy and Engineering Alloys, ASM International, 2008
3. S. Rao and Bb. Parulekar Energy Technology: Non-Conventional, Renewable & Conventional, Khanna Publishers, 3rd Edition, 2014.
4. P.K. Nag, Power plant Engg, Tata Mcgraw Hill publishing company Limited, Fourth edition (19 June 2014)
5. E. E. Khalil, Power Plant Design, Gordon and Breach Science Publisher, Switzerland
6. B.H Khan, Non – conventional Energy Resources, Tata McGraw Hill publishing company Limited, second edition
7. S. Khanna, Introduction to High Temperature Oxidation and Corrosion, ASM International, 01-Jan-2002

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	-	2	3	-	-
CO2	3	-	3	3	3	3
CO3	3	-	3	3	3	2
CO4	3	-	2	3	3	-
CO5	3	-	-	3	-	-

3 – High; **2** – Medium; **1** – Low

<table>
<tr><td colspan="3">Department: Mechanical Engineering</td><td colspan="5">Programme: M.Tech. (Energy Technology)</td></tr>
<tr><td colspan="3">Semester: Third</td><td colspan="3">Course Category Code: PSE5</td><td colspan="2">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2" colspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>MEZ17</td><td colspan="2">Wind Energy Technology</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="9">Understanding of Fluid mechanics</td></tr>
<tr><td rowspan="5">Course Outcome</td><td>CO1</td><td colspan="8">Understand the basics of wind energy characteristics, its measurement, its availability and its application</td></tr>
<tr><td>CO2</td><td colspan="8">Gain knowledge regarding the principle of wind energy conversion and its related concepts</td></tr>
<tr><td>CO3</td><td colspan="8">Analyse the various parameters regarding the performance of wind turbines</td></tr>
<tr><td>CO4</td><td colspan="8">Gain insight into the design and workings of wind turbines and its related components</td></tr>
<tr><td>CO5</td><td colspan="8">Understand the techno-economic feasibilities of wind turbine plant</td></tr>
<tr><td>UNIT I</td><td colspan="6"></td><td colspan="3">Periods: 9</td></tr>
<tr><td colspan="9">Wind resource:Wind characteristics: meteorology of wind – Francis Beaufort scale – wind speed distribution across the world and India – wind speed variation with height – wind speed characteristics – atmospheric turbulence – Gust windspeeds – extreme wind speeds – wind speed prediction and forecasting – wind measurements: Eolian features –biological indicators – rotational anemometers – pressure plate and tube anemometers – hot wire anemometer –Doppler acoustic radar – wind direction measurements – Classification of wind energy conversion systems: HAWT, VAWT – Wind energy scenario in India – Wind energy applications: stand-alone system – grid and hybrid connected systems.</td><td>CO1</td></tr>
<tr><td>UNIT II</td><td colspan="6"></td><td colspan="3">Periods: 9</td></tr>
<tr><td colspan="9">Principle of wind energy conversion: Aerodynamics of horizontal axis wind turbines: actuator disc concept – momentum theory – power coefficient –Betz limit – rotor disc theory – vortex cylinder theory – rotor blade theory – break-down momentum theory –aero-foils and their characteristics – blade geometry – effect of number of blades: solidity – aerodynamics of wind turbine in steady yaw – acceleration potential – stall delay – unsteady flow – aerodynamics of vertical axis turbines – Momentum theories.</td><td>CO2</td></tr>
<tr><td>UNIT III</td><td colspan="6"></td><td colspan="3">Periods: 9</td></tr>
<tr><td colspan="9">Performance of wind turbines, loading estimation: Assessment of performance: power output – constant rotational speed operation – variable-speed operation –estimation of energy capture – wind turbine field testing – wind turbine performance measurement – design loads: basis for loading – national and international standards – turbulence and wakes – extreme loads – fatigue loading – stationary blade loading – blade dynamic loading – hub and low-speed shaft loading – nacelle loading –tower loading.</td><td>CO3</td></tr>
<tr><td>UNIT IV</td><td colspan="6"></td><td colspan="3">Periods: 9</td></tr>
<tr><td colspan="9">Design of wind turbines and control, safety and electrical systems: Design: blades, pitch bearings, rotor hub, gear box, mechanical brake, nacelle, yaw drive, tower and foundation –Stall control – pitch control – yaw control – braking systems – electrical and electronic controllers – electrical power generators: asynchronous generators – DC shunt generator – permanent magnet generator – AC generators – self-excitation of induction generators – power collection systems – lightning protection – power quality assessment – electrical protection – embedded wind power generation</td><td>CO4</td></tr>
<tr><td>UNIT V</td><td colspan="6"></td><td colspan="3">Periods: 9</td></tr>
<tr><td colspan="9">Wind turbine plant installation and economics: Selection of plant site – selection of site – project assessment – site investigation – visual and landscape assessment – noise assessment – ecological assessment – electromagnetic interference – financial assessment –concept of economics – capital costs – revenue requirements – value of wind generated electricity – hidden costs– economic factors –installation methods</td><td>CO5</td></tr>
<tr><td colspan="2">Lecture Periods: 45</td><td colspan="2">Tutorial Periods: -</td><td colspan="3">Practical Periods: -</td><td colspan="3">Total Periods: 45</td></tr>
</table>

Reference Books
1. Johnson, G. L., Wind Energy Systems, Prentice Hall, 1985. 2. Walker, J. F., Wind Energy Technology, John Wiley, 1997. 3. Freris, L. L., Wind Energy Conversion Systems, Prentice Hall, 1990. 4. Spera, D. A., Wind Turbine Technology: Fundamental concepts of wind turbine engineering, ASME Press.

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	-	3	1	3	-
CO2	3	-	3	2	3	-
CO3	3	-	3	2	3	1
CO4	3	-	3	3	3	1
CO5	3	-	3	2	3	-

3 – High; **2** – Medium; **1** – Low

<table>
<tr><td colspan="3">Department: Mechanical Engineering</td><td colspan="8">Programme: M.Tech. (Energy Tecnology)</td></tr>
<tr><td colspan="3">Semester: Third</td><td colspan="4">Course Category Code:PSE5</td><td colspan="4">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2" colspan="2">Course Name</td><td colspan="3">Periods / Week</td><td rowspan="2">Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>MEZ18</td><td colspan="2">Non- Equilibrium and Quantum Thermodynamics</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="9">No prerequisites</td></tr>
<tr><td rowspan="5">Course Outcome</td><td>CO1</td><td colspan="8">Meaning of Entropy through microscopic physics</td></tr>
<tr><td>CO2</td><td colspan="8">Origin of irreversibility in thermodynamic systems, Classical vs Quantum Heat Engines</td></tr>
<tr><td>CO3</td><td colspan="8">Introducing modern laws of non-equilibrium and quantum thermodynamics</td></tr>
<tr><td>CO4</td><td colspan="8">Irreversible processes, coupled phenomena transport, quantum entropy, quantum transport</td></tr>
<tr><td>CO5</td><td colspan="8">Applications extending to diverse domains of energy, biological, computing and finance</td></tr>
<tr><td>UNIT I</td><td colspan="6"></td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="9">Kinetic Theory and Statistical TD - Kinetic theory - introduction, review of equilibrium statistical physics, Boltzmann entropy, Boltzmann equation – approximations, Monte Carlo Simulation</td><td>CO1</td></tr>
<tr><td>UNIT II</td><td colspan="6"></td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="9">Non-Equilibrium and Irreversible TD - Non-equilibrium thermodynamics – linear – nonlinear irreversible systems – fluctuation dissipation theorem, transport phenomena – phenomenological laws, Onsager relations, Non Equilibrium Thermodynamics Simulation</td><td>CO2</td></tr>
<tr><td>UNIT III</td><td colspan="6"></td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="9">Quantum Physics for Quantum TD Foundations - Quantum physics – review, Hamiltonian - Schrodinger equation, Quantum thermodynamics – foundations, Maxwell Boltzmann, Fermi Dirac, Bose Einstein distribution function, Quantum Simulation</td><td>CO3</td></tr>
<tr><td>UNIT IV</td><td colspan="6"></td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="9">Multiscale-Multi-physics Transport Processes- Boltzmann Quantum transport, ballistic and non-ballistic regime, mesoscopic systems, molecular, electron, phonon and photon – transport, Master equations and QBTE Simulation</td><td>CO4</td></tr>
<tr><td>UNIT V</td><td colspan="6"></td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="9">Non-Equilibrium and Quantum Thermodynamics of Complex Systems
Applications – Irreversible processes, Thermoelectric Quantum energy transport, Quantum Biology, Quantum Computing and Finance, Computer Simulation</td><td>CO5</td></tr>
<tr><td colspan="2">Lecture Periods: 45</td><td colspan="2">Tutorial Periods: -</td><td colspan="3">Practical Periods: -</td><td colspan="3">Total Periods: 45</td></tr>
<tr><td colspan="10"><u>Reference Books</u></td></tr>
<tr><td colspan="10">1. Gunter Mahler, Quantum Thermodynamic Processes, CRC Press, Boca Raton, 2015.
2. David J Griffiths, Introduction to Quantum Mechanics, Pearson, London, 2013.
3. Kamran Behnia, Fundamentals of Thermoelectricity, Oxford, London, 2015.
4. Leonard B. Loeb, The Kinetic Theory of Gases, Dover, New York, 2004.
5. S. R. De Groot and P. Mazur, Non Equilibrium Thermodynamics, Dover, Amsterdam, 1984.</td></tr>
</table>

CO	**PO 1**	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**
CO1	3	-	2	1	-	-
CO2	3	-	2	1	-	-
CO3	3	-	2	1	-	-
CO4	3	-	2	1	-	-
CO5	3	-	2	1	-	-

3 – High; **2** – Medium; **1** – Low

Department: **Mechanical Engineering**		Programme: **M.Tech.(Energy Technology)**						
Semester: **Third**		Course Category Code:**PSE5**			Semester Exam Type: **TY**			
Course Code	Course Name	Periods / Week			Credit	Maximum Marks		
		L	T	P		CA	SE	TM
MEZ19	**Advanced and Applied Computational Fluid Dynamics**	**3**	**-**	**-**	**3**	**40**	**60**	**100**
Prerequisite	**A course on Basic CFD is desirable**							

Course Outcome	**CO1**	Exploiting the power of Computational Fluid Dynamics as a prediction tool while minimizing the associated errors and uncertainties
	CO2	Emerging trends in computational algorithms and computational infrastructure for CFD Practice
	CO3	Applying CFD in advanced and complex application domains of engineering and research
	CO4	Understand the core CFD paradigms such as Validation & Verification methodology in CFD, Scalable Extreme Performance CFD Simulations, Using Energy aware/efficient CFD Algorithms/Hardwares, Data driven prediction in CFD
	CO5	Exposure to Coupled Phenomena Modeling

UNIT I	**Periods** : **9**	
Modeling Turbulence-Turbulence – RANS Equations, Discretization, Wall functions, DNS, LES, dynamic mesh implementations, Solution residuals and convergence, validation and verification studies		**CO1**
UNIT II	**Periods** : **9**	
Mesh less Methods - Mesh free method - Smooth Particle Hydrodynamics – features, applications, formulation, Grid based method - Volume of Fluid Method – equations, discretization and algorithm, Immersed boundary method – Navier-Stokes equations, applications		**CO2**
UNIT III	**Periods** : **9**	
Hybrid Methods LBM – Kinetic theory of BTE, BGK Model equation, BCs, Laminar and Turbulent flows		**CO3**
UNIT IV	**Periods** : **9**	
Energy Efficiency in CFD: Computing Hardware Architectures and associated infrastructure for Parallel High Performance CFD – Review of Scientific Computing Paradigms, Heterogeneous Computing, Energy efficient CFD Algorithms		**CO4**
UNIT V	**Periods** : **9**	
Coupled Phenomena Modeling: Fluid Surface/Structure interaction – coupled FVM/FEM algorithms, Compressible Flows, Moving Boundary Flows, Laminar and turbulent Free Surface Flows, Marangoni Flows, Multiphysical MHD and Electrokinetic flow modeling		**CO5**

Lecture Periods: 45	**Tutorial Periods: -**	**Practical Periods: -**	**Total Periods: 45**

Reference Books

1. M. Darwish, L. Mangani, and F. Moukalled (2016), The finite volume method in computational fluid dynamics, Springer, New York.
2. Maddle Stigler (2018), Beginning Serverless Computing, Springer, NewYork.
3. TomislavMaric, Jens Hopken and Kyle Mooney (2014), The OpenFOAM Technology Primer, Sourceflux, Duiburg.
4. SauroSucci (2001), The Lattice Boltzmann Equation for Fluid Dynamics and Beyond, Oxford University Press, Oxford.

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO1	3	-	2	1	-	-
CO2	3	-	2	1	-	-
CO3	3	-	2	1	-	-
CO4	3	-	2	1	-	-
CO5	3	-	2	1	-	-

3 – High; **2** – Medium; **1** – Low

<table>
<tr><td colspan="2">Department: Mechanical Engineering</td><td colspan="4">Programme: M.Tech.(Energy Tecnology)</td><td colspan="4"></td></tr>
<tr><td colspan="2">Semester: Fourth</td><td colspan="4">Course Category Code:PSE 5</td><td colspan="4">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>MEZ20</td><td>Multiscale and Multi-physics Simulation of EnergySystems</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="8">NIL</td></tr>
<tr><td rowspan="5">Course Outcome</td><td>CO1</td><td colspan="7">Multi scale and multi physics modelling paradigm in realizing simulation-based or simulation-driven designs</td></tr>
<tr><td>CO2</td><td colspan="7">Efficiency of macroscopic models as well as accuracy of micro scopic models</td></tr>
<tr><td>CO3</td><td colspan="7">Enable the designing of new emerging technology products</td></tr>
<tr><td>CO4</td><td colspan="7">Improving performance of multiphysics coupled transport in dissipative systems</td></tr>
<tr><td>CO5</td><td colspan="7">Simulation of Multiscale Phenomena in PV, TE and Biological Processes</td></tr>
<tr><td colspan="6">UNIT I</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Macro Scale Phenomena :Modeling Macro scale phenomena – Continuum Hypothesis, Equations of motion, DPD, FEM/FVM</td><td>CO1</td></tr>
<tr><td colspan="6">UNIT II</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Micro-Nano Scale Phenomena: Micro/Nano Scale Modeling – Review of Statistical Thermodynamics, Phase space, Ensembles, LBM, MD, MC</td><td>CO2</td></tr>
<tr><td colspan="6">UNIT III</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Quantum and Molecular Phenomena: Quantum Phenomena – Quantum Theory, Hamiltonian, Schrodinger’s Equation, QM-MM</td><td>CO3</td></tr>
<tr><td colspan="6">UNIT IV</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Multiscale Energy Transport :Photovoltaic and Thermoelectric Energy – Silicon, Thin film, organic polymer PVs, TEG and TEC</td><td>CO4</td></tr>
<tr><td colspan="6">UNIT V</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Multiscale Multiphysics Transport: Biological Processes – Multiscale and Multiphysics analysis of Biomaterials and Biomechanics</td><td>CO5</td></tr>
<tr><td colspan="8">Lecture Periods: 45 Tutorial Periods: - Practical Periods: - Total Periods: 45</td><td></td></tr>
<tr><td colspan="9">Reference Books:
1. Kamran Behnia (2015), Fundamental of Thermoelectricity, Oxford
University Press, London.
2. James Larminie and Andrew Dicks (2003), Fuel Cell Systems Explained,
Wiley, New York.
3. Juan Bisquert (2018), The Physics of Solar Cells, CRC Press, New
4. Weinan E (2011), Principles of Multiscale Modelling, Cambridge
University Press, New York.
5. Martin O. Steinhauser (2017), Computational Multiscale Modeling of
Fluids and Solids, Springer, New York</td></tr>
</table>

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO1	3	-	2	1	-	-
CO2	3	-	2	1	-	-
CO3	3	-	2	1	-	-
CO4	3	-	-	2	-	-
CO5	3	-	-	2	-	-

3 – High; **2** – Medium; **1** – Low