ANNA UNIVERSITY, CHENNAI

UNIVERSITY DEPARTMENTS

REGULATIONS - 2023

CHOICE BASED CREDIT SYSTEM

M.E. ENERGY ENGINEERING

THE VISION OF THE DEPARTMENT OF MECHANICAL ENGINEERING

The Department of Mechanical Engineering strives to be recognized globally for excelling in engineering education and research leading to innovative, entrepreneurial and competent graduates in Mechanical Engineering and allied disciplines.

THE MISSION OF THE DEPARTMENT OF MECHANICAL ENGINEERING

- Providing world class education by fostering effective teaching learning process that is supported through pioneering and cutting-edge research to make impactful contribution to the society.
- Attracting highly motivated students with enthusiasm, aptitude and interest in the field of Mechanical and allied Engineering disciplines.
- Expanding the frontiers of Engineering and science in technological innovation while ensuring academic excellence and scholarly learning in a collegial environment.
- Excelling in industrial consultancy and research leading to innovative technology development and transfer.
- Serving the society with Innovative and entrepreneurially competent graduates for the national and international community towards achieving the sustainable development goals.

REGULATIONS – 2023: CHOICE BASED CREDIT SYSTEM

M.E. ENERGY ENGINEERING

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs) :

The Energy Engineering program seeks to prepare PG students for productive and rewarding careers in the energy arena. The PEOs are listed below:

(i) Acquire knowledge and employability skills in energy sector with requisite skills facilitating quick progress in graduands career

(ii) Inclination towards advanced research for mitigating the shortcomings in energy systems.

(iii) Ascending as an energy consultant/entrepreneur for providing solutions towards improving the efficacy of energy systems.

(iv) Lead an ethical life by engaging in lifelong learning experiences for developing environmentally benign and economically affordable low carbon energy solutions for societal upliftment

PROGRAMME OUTCOMES (POs):

(i) Ability to independently carry out research/investigation and development work to solve practical problems

(ii) Awareness on energy (renewable and non-renewable) and environmental scenario at local, national and global level

(iii) Carry out energy benchmarking in Industries/Commercial Buildings, diagnosing the causes for deviation and suggestions for improving the performance

(iv) Expertise to use various simulation software related to energy systems to identify research gaps and ideate innovations

(v) Optimize energy systems with environmental consciousness for sustainable development.

(vi) Proficiency to document and present a comprehensive technical report on energy related aspects

PEO/PO Mapping:

PEO	PO					
	(i)	(ii)	(iii)	(iv)	(v)	(vi)
(i)	3	3	3	3	3	3
(ii)	3	3	2	3	3	3
(iii)	3	3	3	3	3	3
(iv)	3	2	3	3	3	3

PROGRAM ARTICULATION MATRIX OF ME ENERGY ENGINEERING

Year	Sem.	Courses	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
I	I	Advanced Numerical Methods	3	-	-	1	2	-
		Thermodynamic Analysis of Energy Systems	2.4	1.8	1.5	2.6	1.6	1.3
		Fluid Mechanics and Heat Transfer	3	-	2	3	1.6	1
		Fuels and Combustion	3	2	-	-	3	1.5
		Renewable Energy Systems	3	3	-	-	3	2.2
		Research Methodology and IPR	3	3	2	-	-	-
		Measurements and Controls in Energy Systems	3	-	1	-	-	1.5
	II	Energy Conservation and Management in Industries	3	3	3	-	3	3
		Computational Fluid Dynamics for Energy Systems	2.2	-	3	3	2	-
		Professional Elective I						
		Professional Elective II						
		Analysis and Simulation Laboratory for Energy Engineering	2.3	1.7	3	3	2.7	3
		Summer Internship	3	3	3	3	3	3
II	III	Professional Elective III						
		Professional Elective IV						
		Professional Elective IV						
		Project Work - I	3	3	3	3	3	3
	IV	Project Work - II	3	3	3	3	3	3
PEC		Bio Energy	2	3	-	-	3	2.6
		Wind Energy	2.2	3	-	2.2	3	2.2
		Solar Energy	2.4	3	-	3	3	3
		Hydro Energy	3	3	-	-	3	3
		Polygeneration Systems	2.6	1.8	2.2	-	2.4	2.8
		Waste to Energy conversion Systems	2	2	-	-	3	2.6
		Energy Conservation in Buildings	2.2	2	2.2	-	1.6	2
		Industrial Refrigeration and Air Conditioning Systems	2.6	-	2.2	-	2	2.8
		Design and Analysis of Turbo Machines	3	-	2	2	3	-
		Design of Heat Exchangers	3	-	2	2	3	1
		Advanced Power Plant Engineering	3	2.2	2	-	3	2
		Energy Forecasting, Modelling and Project Management	2.3	1.8	2.8	2.6	2.6	3.0
		Modelling and Analysis of Energy Systems	2.2	1.7	1.7	2.6	2.4	1.7
		Design and Optimization of thermal energy systems	2	1.5	1.8	2.8	2.8	1.5
		Statistical Design and Analysis of Experiments	3	-	1	-	2	1
		Energy Storage Technologies	2	2	-	-	3	2.6
		Fuel Cell Technology	2	3	-	-	3	1
		Hydrogen Generation, Storage and Application	2	3	-	-	3	1
		Nanomaterials for Energy Systems	2.8	2	-	1.75	2.25	2.4
		Nuclear Engineering	2.2	3	-	2.2	3	2.2

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UNIVERSITY DEPARTMENTS
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CHOICE BASED CREDIT SYSTEM
M.E. ENERGY ENGINEERING

I TO IV SEMESTER CURRICULUM AND SYLLABI

SEMESTER I

SL. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY / PRACTICAL								
1.	MA3155	Advanced Numerical Methods	FC	4	0	0	4	4
2.	EY3152	Thermodynamic Analysis of Energy Systems	PCC	3	1	0	4	4
3.	EY3151	Fluid Mechanics and Heat Transfer	PCC	3	1	0	4	4
4.	EY3101	Fuels and Combustion	PCC	3	0	2	5	4
5.	EY3153	Renewable Energy Systems	PCC	3	0	2	5	4
6.	EY3154	Measurements and Controls in Energy Systems	FC	3	0	0	3	3
7.	RM3151	Research Methodology and IPR	MC	2	1	0	3	3
			TOTAL	**21**	**3**	**4**	**28**	**26**

SEMESTER II

SL. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.	EY3201	Energy Conservation and Management in Industries	PCC	3	0	2	5	4
2.	EY3251	Computational Fluid Dynamics for Energy Systems	PCC	3	1	0	4	4
3.		Professional Elective I	PEC	3	0	0	3	3
4.		Professional Elective II	PEC	3	0	0	3	3
PRACTICAL								
5.	EY3211	Analysis and Simulation Laboratory for Energy Engineering	PCC	0	0	4	4	2
6.	EY3212	Summer Internship*	EEC	*	*	*	*	2
			TOTAL	**12**	**1**	**6***	**19***	**18**

***** To be carried out in an energy intensive industry (HT Consumer) during 2^{nd} semester vacation

* Minimum period of training = 4 weeks & evaluation to be carried out on 1^{st} week of 3^{rd} sem

SEMESTER III

SL. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.		Professional Elective III	PEC	3	0	0	3	3
2.		Professional Elective IV	PEC	3	0	0	3	3
3.		Professional Elective V	PEC	3	0	0	3	3
PRACTICAL								
4.	EY3311	Project Work - I	EEC	0	0	12	12	6
			TOTAL	**9**	**0**	**12**	**21**	**15**

SEMESTER IV

SL. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
PRACTICAL								
1.	EY3411	Project Work - II	EEC	0	0	24	24	12
			TOTAL	**0**	**0**	**24**	**24**	**12**

Total credits for the programme = 26 + 18 + 15 +12 = 71

Students are permitted to

(i) ***Study any 2 courses - equivalent to the subjects mentioned in the curriculum - in National Programme on Technology Enhanced Learning (NPTEL), Govt. of India***

AND/OR

(ii) ***Study any 2 TECHNICAL courses for consideration under Program Electives amongst the core/elective courses offered in the University Departments***

Prior approval of (1) Faculty Adviser, (2) Professor–i/c of PG Programme, (3) HoD – Dept. of Mech. Engg., and (4) Chairperson – Faculty of Mechanical Engineering is to be obtained for the above.

FOUNDATION COURSES (FC)

Sl. No	Code No.	Course Title	Periods per week			Credits	Semester
			Lecture	Tutorial	Practical		
1.	MA3155	Advanced Numerical Methods	4	0	0	4	1
2.	EY3154	Measurements and Controls in Energy Systems	3	0	0	3	1
						7	

PROFESSIONAL CORE COURSES (PCC)

Sl. No	Code No.	Course Title	Periods per week			Credits	Semester
			Lecture	Tutorial	Practical		
1.	EY3152	Thermodynamic Analysis of Energy Systems	3	1	0	4	1
2.	EY3151	Fluid Mechanics and Heat Transfer	3	1	0	4	1
3.	EY3101	Fuels and Combustion	3	0	2	4	1
4.	EY3153	Renewable Energy Systems	3	0	2	4	1
5.	EY3201	Energy Conservation and Management in Industries	3	0	2	4	2
6.	EY3251	Computational Fluid Dynamics for Energy Systems	3	1	0	4	2
7.	EY3211	Analysis and Simulation Laboratory for Energy Engineering	0	0	4	2	2
						26	

PROFESSIONAL ELECTIVE COURSES

SL. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
1.	EY3001	Bio Energy	PEC	3	0	0	3	3
2.	EY3002	Wind Energy	PEC	3	0	0	3	3
3.	EY3003	Solar Energy	PEC	3	0	0	3	3
4.	EY3004	Hydro Energy	PEC	3	0	0	3	3
5.	EY3053	Polygeneration Systems	PEC	3	0	0	3	3
6.	EY3054	Waste to Energy conversion Systems	PEC	3	0	0	3	3
7.	EY3055	Energy Conservation in Buildings	PEC	3	0	0	3	3
8.	EY3056	Industrial Refrigeration and Air Conditioning Systems	PEC	3	0	0	3	3
9.	EY3064	Design and Analysis of Turbo Machines	PEC	3	0	0	3	3
10.	EY3065	Design of Heat Exchangers	PEC	3	0	0	3	3
11.	EY3051	Advanced Power Plant Engineering	PEC	3	0	0	3	3
12.	EY3057	Energy Forecasting, Modelling and Project Management	PEC	3	0	0	3	3
13.	EY3058	Modelling and Analysis of Energy Systems	PEC	3	0	0	3	3
14.	EY3059	Design and Optimization of thermal energy systems	PEC	3	0	0	3	3
15.	EY3060	Statistical Design and Analysis of Experiments	PEC	3	0	0	3	3
16.	EY3061	Energy Storage Technologies	PEC	3	0	0	3	3
17.	EY3052	Fuel Cell Technology	PEC	3	0	0	3	3
18.	EY3062	Hydrogen Generation, Storage and Application	PEC	3	0	0	3	3
19.	EY3063	Nanomaterials for Energy Systems	PEC	3	0	0	3	3
20.	EY3005	Nuclear Engineering	PEC	3	0	0	3	3

MANDATORY COURSES (MC)

Sl. No	Code No.	Course Title	Periods per week			Credits	Semester
			Lecture	Tutorial	Practical		
1	RM3151	Research Methodology and IPR	2	1	0	3	1
					Total Credits	**3**	

EMPLOYABILITY ENHANCEMENT COURSES (EEC)

Sl. No	COURSE CODE	Course Title	Periods per week			Credits	Semester
			Lecture	Tutorial	Practical		
1	EY3212	Summer Internship	*	*	*	2	2
2	EY3311	Project Work - I	0	0	12	6	3
3	EY3411	Project Work - II	0	0	24	12	4
					Total Credits	**20**	

Summary

S.No.	M.E. (Energy Engineering)					
	Subject Area	Credits per Semester				Credits Total
		I	II	III	IV	
1.	FC	7	-	-	-	7
2.	PCC	16	10	-	-	26
3.	PEC	-	6	9	-	15
4.	MC	3	-	-	-	3
5.	EEC	-	2	6	12	20
	Total Credit	**26**	**18**	**15**	**12**	**71**

MA3155 **ADVANCED NUMERICAL METHODS** **L T P C**

4 0 0 4

OBJECTIVES:

- To impart knowledge in understanding the advantages of various solution procedures of solving the system of linear and nonlinear equations.
- To give a clear picture about the solution methods for solving the BVPs and the system of IVPs.
- To acquire knowledge in solving time dependent one and two dimensional parabolic PDEs by using various methodologies.
- To strengthen the knowledge of finite difference methods for solving elliptic equations.
- To get exposed to the ideas of solving PDEs by finite element method.

UNIT I ALGEBRAIC EQUATIONS 12

Systems of linear equations: Gauss Elimination method, pivoting techniques, Thomas algorithm for tridiagonal system – Jacobi, Gauss Seidel, SOR iteration methods - Systems of nonlinear equations: Fixed point iterations, Newton Method, Eigenvalue problems: power method, Faddeev – Leverrier Method.

UNIT II ORDINARY DIFFERENTIAL EQUATIONS 12

Runge Kutta Methods for system of IVPs, numerical stability, Adams-Bashforth multistep method, solution of stiff ODEs, shooting method, BVP: Finite difference method, collocation method, orthogonal collocation method, Galerkin finite element method.

UNIT III FINITE DIFFERENCE METHOD FOR TIME DEPENDENT PARTIAL DIFFERENTIAL EQUATION 12

Parabolic equations: explicit and implicit finite difference methods, weighted average approximation - Dirichlet and Neumann conditions – Two dimensional parabolic equations – ADI method; First order hyperbolic equations – method of characteristics, Lax - Wendroff explicit and implicit methods; numerical stability analysis, method of lines – Wave equation: Explicit scheme-Stability of above schemes.

UNIT IV FINITE DIFFERENCE METHODS FOR ELLIPTIC EQUATIONS 12

Laplace and Poisson's equations in a rectangular region: Five point finite difference schemes, Leibmann's iterative methods, Dirichlet and Neumann conditions – Laplace equation in polar coordinates: finite difference schemes – approximation of derivatives near a curved boundary while using a square mesh.

UNIT V FINITE ELEMENT METHOD 12

Partial differential equations – Finite element method - collocation method, orthogonal collocation method, Galerkin finite element method.

TOTAL: 60 PERIODS

OUTCOMES:

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

CO1 Get familiarized with the methods which are required for solving system of linear, nonlinear equations and eigenvalue problems.

CO2 Solve the BVPs and the system of IVPs by appropriate methods discussed.

CO3 Solve time dependent parabolic PDEs by using various methodologies up to dimension two.

CO4 Solve elliptic equations by finite difference methods.

CO5 Use the ideas of solving PDEs by finite element method.

REFERENCES:

1. Burden, R.L., and Faires, J.D., “Numerical Analysis – Theory and Applications”, Cengage Learning, India Edition, New Delhi, 2010.
2. Gupta S.K., “Numerical Methods for Engineers”, New Age Publishers, 3rd Edition, New Delhi, 2015.
3. Jain M. K., Iyengar S. R. K., Jain R.K., “Computational Methods for Partial Differential Equations”, New Age Publishers, 2nd Edition, New Delhi, 2016.
4. Morton K.W. and Mayers D.F., “Numerical solution of partial differential equations”, Cambridge University press, Cambridge, 2005.
5. Sastry S.S., "Introductory Methods of Numerical Analysis", Prentice - Hall of India Pvt. Limited, 5th Edition, New Delhi, 2012.
6. Saumyen Guha and Rajesh Srivastava, “Numerical methods for Engineering and Science”, Oxford Higher Education, New Delhi, 2010.

CO-PO Mapping:

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

EY3152	THERMODYNAMIC ANALYSIS OF ENERGY SYSTEMS	L	T	P	C
		3	1	0	4

OBJECTIVE:

The major objective of this course is to introduce the advanced thermodynamic concepts which are useful in understanding fundamental concepts of availability, entropy generation, properties of matter and to apply in various Engineering problems involving energy transfer, chemical processing, etc. The course will focus on both energy producing and consuming thermodynamic cycle's system energy and exergy analysis.

UNIT – I FUNDAMENTAL LAWS, CLOSED and OPEN SYSTEMS 12

Zeroth, First and Second law of Thermodynamics, Fundamental equations for closed systems, Process, Relations, Second law efficiency for a closed system, Fundamental equations for open systems, Steady state operations, Flow in channel, turbine and compressors

UNIT – II ENTROPY GENERATION 12

Lost Available Work, Process – non flow and steady flow, Mechanisms for entropy generation – Heat Transfer, friction, mixing – entropy generation minimization techniques, Internal flow, heat transfer, fluid flow, electrical systems - entropy minimization to Constructional laws.

UNIT – III THERMODYNAMIC PROPERTIES of MATTER 12

General properties of perfect and ideal gases, Van der walls fluids, Virial fluids, Maxwell relations. Generalized relations for changes in entropy – internal energy and enthalpy – C_p and C_V. Clausius Clapeyron equation, Joule – Thomson coefficient. Bridgman tables for thermodynamic relations, Fundamental property relations for systems of variable composition. Partial molar properties. Ideal and real gas mixtures

UNIT – IV THERMODYNAMIC CYCLES 12

General features of cycles, Vapour Cycles – working fluids, Rankine Cycles and its modification, Kalina Cycle, Supercritical Cycles – Gas Power Cycles – Refrigeration and Heat Pump Cycles - Combined Cycles and Cogeneration

UNIT – V ENERGY and EXERGY ANALYSIS 12

Energy and Exergy Approach, Energy and Exergy of Fuels, Combustion processes, Exergy Analysis of Heat exchangers, Boilers, Heat Pumps, Turbo machines, and Internal Combustion Engines

TOTAL: 60 PERIODS

OUTCOMES:

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

CO 1 Understand the thermodynamic system, and apply various thermodynamic relations

CO 2 Analyze the entropy generation in various processes

CO 3 Predict the behavior of real gas and calculate the properties of gas mixtures

CO 4 Apply various thermodynamic cycles for various work producing and consuming systems

CO 5 Apply the thermodynamic knowledge for analyzing the energy and exergy concepts in different applications.

REFERENCES

1. Bejan, A., “Advanced Engineering Thermodynamics”, John Wiley and Sons, 2016.
2. Kalyan Annamalai, Ishwar K. Puri, Milind A. Jog., “Advanced thermodynamics engineering”, CRC press, 2011
3. Kuo, K.K., “Principles of Combustion”, John Wiley and Sons, 2005
4. Kenneth Wark Jr., “Advanced Thermodynamics for Engineers”, McGraw – Hill Inc., 1995.
5. Lucien Borel, Daniel Favrat, “Thermodynamics and Energy Systems Analysis: From Energy to Exergy”, CRC Press, 2010

CO – PO MAPPING:

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1	3	1	-	3	1	1
2	1	2	1	2	2	-
3	3	2	3	3	2	1
4	2	-	1	2	1	-
5	3	2	1	3	2	2
Avg.	**2.4**	**1.8**	**1.5**	**2.6**	**1.6**	**1.3**

EY3151 FLUID MECHANICS AND HEAT TRANSFER

	L	T	P	C
	3	1	0	4

OBJECTIVE:

The main objective of the course is to impart knowledge to students on the concepts of fluid kinematics, boundary layer theory, incompressible and compressible fluid flow analysis. The course is also useful to enhance the student knowledge on various modes of heat transfer and the applications of heat transfer.

UNIT – I FLUID KINEMATICS AND BOUNDARY LAYER THEORY 12

Three dimensional forms of governing equations – Mass, Momentum, and their engineering applications. Rotational and irrotational flows – vorticity – stream and potential functions.
Boundary Layer – displacement, momentum and energy thickness – laminar and turbulent boundary layers in flat plates and circular pipes.

UNIT – II INCOMPRESSIBLE AND COMPRESSIBLE FLOWS 12

Laminar flow between parallel plates – flow through circular pipe – friction factor – smooth and rough pipes – Moody diagram – losses during flow through pipes. Pipes in series and parallel – transmission of power through pipes.
One dimensional compressible flow analysis – flow through variable area passage – nozzles and diffusers.

UNIT – III CONDUCTION AND CONVECTION HEAT TRANSFER 12

Conduction: Governing Equation and Boundary conditions, Extended surface heat transfer, Transient conduction – Use of Heisler-Grober charts, Conduction with moving boundaries, Stefan and Neumann problem.
Energy equation - Analogy between heat and momentum transfer – Reynolds, Colburn, Prandtl turbulent flow in a tube – High speed flows – Convection with phase change – Condensation, Boiling.

UNIT – IV RADIATION HEAT TRANSFER 12

Surface radiation – View factor analysis, Gas Radiation - Radiative Transfer Equation (RTE), Radiation properties of a participating medium, Use of Hottel's Graph, Correction factor analysis - Inverse problems in radiation transfer.

UNIT – V HEAT EXCHANGER AND HEAT PIPE 12

Heat exchanger: Classification, sizing, and rating problems – Bell Delaware method - Є-NTU method – thermo-hydraulic performance of compact heat exchanger.
Heat Pipes: Classification, Thermal analysis - performance improvement techniques.

TOTAL: 60 PERIODS

OUTCOMES:

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

CO 1 Identify, formulate, and analyze the governing equations for various engineering applications.

CO 2 Learn the flow concepts of incompressible and compressible flow.

CO 3 Solve the conduction and convection heat transfer problems.

CO 4 Understand the importance of radiation heat transfer in gases and inverse solution methods.

CO 5 Design a heat exchanger and heat pipe as per the industrial needs.

REFERENCES:

1. Yunus A Cengel and John M Cimbala, "Fluid Mechanics Fundamentals and Applications," McGraw-Hill, 2018.
2. Venkateshan S P., "Heat Transfer ", Ane Books Pvt. Ltd, 2016
3. Holman J P, "Heat Transfer", McGraw-Hill, 2010.
4. Ozisik M N., "Heat Transfer – A Basic Approach", McGraw Hill Co, 1985.
5. Adrian Bejan, Convection Heat Transfer, Wiley, Fourth Edition, 2013
6. Bahman Zohuri, "Heat Pipe Design and Technology", Taylor and Francis Group, LLC, 2011.

CO – PO MAPPING

CO	PO					
	1	2	3	4	5	6
1	3	-	-	3	1	1
2	3	-	-	3	1	1
3	3	-	2	3	2	1
4	3	-	2	3	2	1
5	3	-	2	3	2	1
Avg.	**3**	**-**	**2**	**3**	**1.6**	**1**

EY3101	FUELS AND COMBUSTION	L	T	P	C
		3	0	2	4

OBJECTIVE:
The objective of this course is to provide a holistic view on combustion mechanism, devices used for combustion and emissions from combustion of different types of fuels.

UNIT – I COMBUSTION 12

Combustion: Stoichiometry, thermodynamics, Nature and types of combustion processes, Mechanism, flame propagation, various methods of flame stabilization, ignition temperature, flash and fire points, calorific intensity, theoretical flame temperature. Combustion calculations, theatrical air requirements, flue gas analysis, combustion kinetics – H_2-O_2 reactions and HC-O_2 reactions, low-temperature combustion.

UNIT – II SOLID FUELS 12

Solid fuels – Classification, preparation, cleaning, handling, analysis, ranking and properties – action of heat, oxidation, hydrogenation, carbonization, liquefaction, and gasification.

UNIT – III LIQUID & GASEOUS FUELS 12

Liquid fuels: Classification- production- composition, petroleum refining, properties, testing – flow test, smoke points, storage, and handling. Secondary liquid fuels –refining, cracking, fractional distillation, polymerization. Modified and synthetic liquid fuels, Biodiesel, Gasohol, ASTM methods of testing the fuels.
Gaseous fuels: Types- production-purification, Fuels for SI &CI engines, knocking and octane number, anti-knock additives, fuels for jet engines and rockets, hydrogen combustion.

UNIT – IV COMBUSTION DEVICES 12

Basic features of burner, types of solid, liquid, and gaseous fuel burners, design consideration of different types of burners, recuperative and regenerative burners, Pulverised fuel furnaces–fixed, entrained, and fluidized bed systems.

UNIT – V EMISSION FROM COMBUSTION 12

Emission from combustion of solid fuel fired devices- Source, control, and measurement - Emission from combustion of liquid and gaseous fuel – Source, control and measurement, Flue gas analysis by chromatography and sensor techniques. fire and explosions in the production, storage, and utilization of both conventional and alternative fuels. Emission standards: Global and Indian

TOTAL: 60 PERIODS

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

- CO1 Understand the mechanism of combustion and combustion calculations
- CO2 Process and analyze solid fuels and apply appropriate testing methods
- CO3 Recognise the different gaseous and gaseous fuel for suitable applications and know analysis of gaseous fuels.
- CO4 Recognize and select the proper combustion devices for various fuels.
- CO5 Acknowledge the sources of pollution from combustion of various fuel and suggest methods of control and monitoring.

REFERENCES:

1. Samir Sarkar, “Fuels and Combustion”, Orient Longman Pvt. Ltd, 3rd edition, 2009
2. H. Joshua Philips, “Fuels – Solids, liquids and gases – Their analysis and valuation”, Biobliolife Publisher, 2008
3. Stephen R Turns, “An introduction to combustion: Concept and applications”, Tata Mc. Graw Hill, 3rd edition, 2012
4. D P Mishra, “Fundamentals of Combustion”, 1st edition, University Press, 2010
5. S.P. Sharma and C. Mohan, “Fuels and combustion”, Tata McGraw-Hill,1984
6. R. Mukhopadhyay and Sriparna Datta, “Engineering Chemistry”, Newage International Pvt. Ltd, 2007

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Practical

1. Proximate analysis of a given biofuel
2. Estimation of calorific value of any solid fuels using bomb calorimeter
3. Computation of calorific value of liquid fuels using Junkers gas calorimeter
4. Combustion of fuel in boiler with different excess air
5. Evaluating and comparing the efficiency of conventional stove and improved (energy efficient) cook stoves
6. Testing of biomass Gasifier in updraught / downdraught mode
7. Study of biogas plant – fixed dome and floating drum model
8. Synthesis of biodiesel – energy and mass balancing
9. Performance evaluation of engine on biodiesel
10. Comparison of combustion and emissions of B0 and B100

TOTAL: 15 PERIODS

CO – PO MAPPING:

CO	PO					
	1	2	3	4	5	6
1	3	2	-	-	3	1
2	3	1	-	-	3	-
3	3	1	-	-	3	-
4	3	1	-	-	3	-
5	3	2	-	-	3	2
Avg	3	2	-	-	3	1.5

EY3153 RENEWABLE ENERGY SYSTEMS

L	T	P	C
3	0	2	4

OBJECTIVE:

Acquaintance with the Indian and Global energy scenario and to edify on the potential and prospects of various renewable energy technologies.

UNIT – I ENERGY AND ENVIRONMENT 9L

Indian energy scenario - Potential of various renewable energy sources - Greenhouse effect – Ozone depletion - Climate Change – UNFCCC - Energy Pricing – Fuel and Energy Substitution

UNIT – II SOLAR ENERGY 9L+15P

Solar radiation – Measurements of solar radiation – Solar spectrum - Solar thermal collectors – Solar thermal applications – thermal energy storage – Fundamentals of solar photo voltaic conversion – Solar cells – Solar PV Systems – Solar PV applications.

UNIT – III WIND ENERGY 9L+3P

Wind data and energy estimation – Betz limit - Site selection for windfarms – characteristics - Wind resource assessment – Windmills – Accessories – Environmental issues - Applications.

UNIT – IV BIO-ENERGY 9L+9P

Bio resources – Thermochemical Conversion: combustion, gasification, pyrolysis and carbonisation – Biochemical conversion: Biomethanation, Fermentation – Physiochemical : Biodiesel, Briquetting and Pelletisation – Applications

UNIT – V HYDRO, GEOTHERMAL & HYBRID ENERGY SYSTEMS 9L+3P

Small hydro - Tidal energy – Wave energy – OTEC – Geothermal energy – Hybrid systems – Environmental impacts

TOTAL: 75 PERIODS

OUTCOMES:

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

CO1 Comprehend on the Indian energy scenario
CO2 Design a Solar Thermal / PV system for any requirement
CO3 Estimate the available wind energy in a particular site
CO4 Suggest suitable conversion mechanism for generating power from Biomass
CO5 Elucidate on the technologies for harnessing power from ocean and geothermal energy.

REFERENCES:

1. Godfrey Boyle, "Renewable Energy, Power for a Sustainable Future", Oxford University Press, 2017, Fourth Edition.
2. Rai.G.D., "Non-Conventional Energy Sources", Khanna Publishers, 2014, Sixth Edition
3. S. P. Sukhatme, J K. Nayak, "Solar Energy", McGraw Hill, 2017, Fourth Edition.
4. B H Khan, "Non-Conventional Resources", McGraw Hill, 2016, Third Edition.
5. John Twidell, "Renewable Energy Resources", Routledge, 2022, Fourth Edtion .

Practical

1. Study of Direct and diffused beam solar radiation
2. Performance evaluation of Solar Flat Plate Collector
3. Determining the I-V characteristics of Solar PV panel
4. Performance evaluation of solar cookers (box type and concentrating type)
5. Determining the I-V Characteristics of a Fuel Cell
6. Performance evaluation of a green hydrogen generation and storage system
7. Performance evaluation of wind turbine
8. Performance evaluation of different turbines employed in hydro power plant
9. Study of Biomethanation plant
10. Study of Biomass briquetting plant

TOTAL: 15 PERIODS

CO – PO MAPPING:

CO	PO					
	1	2	3	4	5	6
1	-	3	-	-	3	3
2	3	3	-	-	3	2
3	3	3	-	-	3	2
4	3	3	-	-	3	2
5	3	3	-	-	3	2
Avg	**3**	**3**	**-**	**-**	**3**	**2.2**

EY3154 MEASUREMENTS AND CONTROLS IN ENERGY SYSTEMS

L	T	P	C
3	0	0	3

OBJECTIVE:

The primary goal of this course is to enrich the students understanding of different measuring instruments, methodologies, and the significance of error and uncertainty analysis. Additionally, this course will equip students with the skills required to design appropriate control unit for a range of thermal systems.

UNIT – I BASICS OF MEASUREMENTS 9

Introduction, general measurement system, Signal flow diagram of measurement system, Inputs and their methods of correction, Presentation of experimental data, Errors in measurement, Propagation of errors, Uncertainty analysis, Regression analysis, Transient response – zeroth, first and second order measurement systems

UNIT – II THERMOMETRY AND HEAT FLUX MEASUREMENT 9

Overview of thermometry, Thermoelectric temperature measurement, Resistance thermometry, Pyrometer, Other methods and Calibration procedure, Challenges in temperature measurements, Principles of Heat flux measurement.

UNIT – III PRESSURE, FLOW AND THERMAL PROPERTY MEASUREMENT 9

Different pressure measurement instruments and their comparison, Transient response of pressure transducers, Flow Measurement, Flow obstruction methods, Magnetic flow meters, Interferometer, LDA, Other methods, Thermo-physical property measurement - Steady and Unsteady methods for solids, fluids and PCMs

UNIT – IV CONTROL SYSTEMS, COMPONENTS, AND CONTROLLERS 9

Introduction, Open and closed loop control systems, Transfer function. Types of feedback and feedback control system characteristics – Control system parameters – DC and AC servomotors, servo amplifier, potentiometer, synchro transmitters, synchro receivers, synchro control transformer, stepper motors - Continuous, Discontinuous and Composite control modes – Analog and Digital controllers.

UNIT – V DESIGN OF MEASUREMENT AND CONTROL SYSTEMS 9

Data logging and acquisition - Integration of industrial instrumentation systems and monitoring, sensors for error reduction, elements of computer interfacing, timers and counters, designing measurement and control systems for specific applications, fault finding, and computer-based controls.

TOTAL: 45 PERIODS

OUTCOMES:

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

CO1 Understand the concepts of errors in measurements, statistical analysis of data, regression analysis, correlation, and estimation of uncertainty.
CO2 Select appropriate sensors for measurement of specific parameters/properties with required accuracy.
CO3 Carry out calibration and evaluate measurement systems using uncertainty analysis
CO4 Distinguish between measurement and control systems, and use appropriate control system for an application
CO5 Construct a complete control system for a thermal application.

REFERENCES:

1. J. P. Holman, "Experimental methods for Engineers", Tata McGraw-Hill, 8th Edition, 2018
2. S. P. Venkateshan, "Mechanical Measurements", Springer, 2nd Edition, 2022
3. Ernest O Doebelin and Dhanesh N. Manik, "Measurement systems: Application and design", Tata McGraw Hill publications, 7th Edition, 2019

4. Thomas G Beckwith, Roy D. Marangoni, and John H. Lienhard, “Mechanical Measurements” Pearson publications, 6th Edition, 2006
5. A. Morris, "Measurement and Instrumentation Principles," Oxford, UK, 3rd Edition, 2015
6. Nakra, B.C., Choudhry K.K., “Instrumentation, Measurements and Analysis”, Tata McGraw Hill, New Delhi, 4th Edition, 2016
7. William Bolton, “Industrial Control & Instrumentation”, Longman Scientific & Technical, 1991

CO – PO MAPPING:

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1	3	-	1	-	-	2
2	3	-	1	-	-	-
3	3	-	-	-	-	1
4	3	--	-	-	-	-
5	3		-	-	-	-
Avg	**3**	**-**	**1**	**-**	**-**	**1.5**

RM3151 RESEARCH METHODOLOGY AND IPR **L T P C**
2 1 0 3

OBJECTIVES:

To impart knowledge on

- Formulation of research problems, design of experiment, collection of data, interpretation and presentation of result
- Intellectual property rights, patenting and licensing

UNIT I RESEARCH PROBLEM FORMULATION 9

Objectives of research, types of research, research process, approaches to research; conducting literature review- information sources, information retrieval, tools for identifying literature, Indexing and abstracting services, Citation indexes, summarizing the review, critical review, identifying research gap, conceptualizing and hypothesizing the research gap

UNIT II RESEARCH DESIGN AND DATA COLLECTION 9

Statistical design of experiments- types and principles; data types & classification; data collection - methods and tools

UNIT III DATA ANALYSIS, INTERPRETATION AND REPORTING 9

Sampling, sampling error, measures of central tendency and variation,; test of hypothesis- concepts; data presentation- types of tables and illustrations; guidelines for writing the abstract, introduction, methodology, results and discussion, conclusion sections of a manuscript; guidelines for writing thesis, research proposal; References – Styles and methods, Citation and listing system of documents; plagiarism, ethical considerations in research

UNIT IV INTELLECTUAL PROPERTY RIGHTS 9

Concept of IPR, types of IPR – Patent, Designs, Trademarks and Trade secrets, Geographical indications, Copy rights, applicability of these IPR; , IPR & biodiversity; IPR development process, role of WIPO and WTO in IPR establishments, common rules of IPR practices, types and features of IPR agreement, functions of UNESCO in IPR maintenance.

UNIT V PATENTS 9

Patents – objectives and benefits of patent, concept, features of patent, inventive steps, specifications, types of patent application; patenting process - patent filling, examination of patent, grant of patent, revocation; equitable assignments; Licenses, licensing of patents; patent agents, registration of patent agents.

TOTAL: 45 PERIODS

COURSE OUTCOMES

Upon completion of the course, the student can

CO1: Describe different types of research; identify, review and define the research problem

CO2: Select suitable design of experiment s; describe types of data and the tools for collection of data

CO3: Explain the process of data analysis; interpret and present the result in suitable form

CO4: Explain about Intellectual property rights, types and procedures

CO5: Execute patent filing and licensing

REFERENCES:

1. Cooper Donald R, Schindler Pamela S and Sharma JK, “Business Research Methods”, Tata McGraw Hill Education, 11e (2012).
2. Soumitro Banerjee, “Research methodology for natural sciences”, IISc Press, Kolkata, 2022.
3. Catherine J. Holland, “Intellectual property: Patents, Trademarks, Copyrights, Trade Secrets”, Entrepreneur Press, 2007.

4. David Hunt, Long Nguyen, Matthew Rodgers, “Patent searching: tools & techniques”, Wiley, 2007.
5. The Institute of Company Secretaries of India, Statutory body under an Act of parliament, “Professional Programme Intellectual Property Rights, Law and practice”, September 2013.

EY3201 ENERGY CONSERVATION AND MANAGEMENT IN INDUSTRIES

L	T	P	C
3	0	2	4

OBJECTIVE:

To understand the necessity of energy audits, its deliverables, performance evaluation, economics and energy conservation avenues in various Thermal & Electrical Utilities in the Industries

UNIT – I ENERGY MANAGEMENT 9L+6P

Energy audit - need – types – methodology – barriers - analysis on energy costing and sharing - bench marking - billing parameters in TANGEDCO – DSM - instruments for energy audit – energy labeling

UNIT – II BOILERS, FURNACES AND THERMIC FLUID HEATERS 9L+8P

Types - Performances evaluation via direct and indirect method – energy conservation avenues.
Steam: Properties - Assessment of distribution losses - trapping - recovery systems

UNIT – III HVAC AND WASTE HEAT RECOVERY 9L+8P

VCRS – performance assessment – energy savings opportunities – VAM: working, types, benefits, comparison with vapor compression system.
WHR systems: Types – Benefits. Polygeneration. Cooling towers

UNIT – IV ELECTRICAL SYSTEMS 9L+8P

Energy conservation in Transformers – Cable loss estimation - Power factor improvement – Harmonics – quantification and remedial measures
Performance assessment and energy conservation avenues in:
Motors - Fans - Blowers – Pumps – Air Compressors - Illumination Systems

UNIT – V FINANCIAL MANAGEMENT 9L

Energy Monitoring and Targeting – CUSUM - Financial analysis techniques: discounted and non-discounted – Depreciation - Sensitivity Analysis - Financing Options - ESCOs – PAT scheme – carbon credits

TOTAL: 75 PERIODS

OUTCOMES:

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

CO1 Analyse EB bills and kVA demand of Industries for possible cost reduction
CO2 Diagnose the cause for under performance of thermal utilities and suggest suitable remedial measures thereof
CO3 Analyse the factors affecting the COP of a HVAC system
CO4 Suggest measures for energy conservation in industrial electrical utilities
CO5 Recommend Go/No-Go for energy conservation projects based on their economics

REFERENCES:

1. Energy Manager Training Manual (4 Volumes) available at https://aipnpc.org/Guidebooks.aspx
   Guidebooks for National Certification Examination, Bureau of Energy Efficiency (BEE), Government of India
2. L.C. Witte, P.S. Schmidt, D.R. Brown, “Industrial Energy Management and Utilisation” Hemisphere Publication, Washington, 1988.
3. Stephen A. Roosa, Steve Doty, Wayne.C.Turner, “Energy Management Hand book”, River Pubishers, 2018
4. W.R. Murphy and G. McKay “Energy Management”, Elsevier, 2007

5. Eastop.T.D & Croft D.R, “Energy Efficiency for Engineers and Technologists”, Longman Scientific & Technical, 1990.
6. Albert Thumann, Terry Niehus, William J.Younger, “Handbook of Energy Audits”, River Publishers, Ninth Edition, 2012

Practical

1. Study of energy audit instruments (flue gas analyser, calorimeter, pitot tube, digital pressure indicator, differential manometer, anemometer – vane type and thermal type, digital tachometer - contact/non-contact, stroboscope, hygrometer, temperature indicator - contact type and non-contact type, ultrasonic leak detector, ultrasonic flow meter, lux meter, energy manager, harmonic analyzer, KVA demand analyser)
2. Performance evaluation of boiler adopting direct and indirect method
3. Determining the efficiency of a simple impulse steam turbine
4. Assessment of performance of steam condensers
5. Determination of steam rate and heat rate of Rankine Cycle
6. Performance evaluation of air compressors and computing its specific energy consumption and cost of compressed air
7. Determining the characteristics of an induction motor and computing its efficiency adopting direct method
8. Determination of pump & pumping system characteristics (pump curve, system curve and BEP)
9. Comparison on the effect of different discharge control techniques in pumps (VFD, throttling and bypass mode) with respect to specific energy consumption
10. Analysis of various luminaries and evaluation of their efficacy
11. Determination of characteristic curves of blowers and comparison of its characteristics upon subjecting it to damper control at inlet and discharge.
12. Determination of range and effectiveness of cooling tower
13. Comparison on the effectiveness of shell and tube, pipe-in-pipe and plate heat exchangers
14. Estimation of CoP of a typical VCRS system at different condenser and evaporator temperatures

CO – PO MAPPING:

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1	3	3	3	-	3	3
2	3	3	3	-	3	3
3	3	3	3	-	3	3
4	3	3	3	-	3	3
5	3	3	3	-	3	3
Avg	**3**	**3**	**3**	**-**	**3**	**3**

EY3251 COMPUTATIONAL FLUID DYNAMICS FOR ENERGY SYSTEMS

	L	T	P	C
	3	1	0	4

OBJECTIVE:

To make students familiarize with the concepts of discretization techniques using finite difference and finite volume method for various transport phenomena related problems.

UNIT – I GOVERNING DIFFERENTIAL EQUATIONS AND DISCRETISATION TECHNIQUES 12

Basics of Heat Transfer, Fluid flow – Mathematical description of fluid flow and heat transfer – Conservation of mass, momentum, energy, and chemical species - Classification of partial differential equations – Initial and Boundary Conditions – Discretization techniques using finite difference methods – Taylor's Series - Uniform and non-uniform Grids, Numerical Errors, Grid Independence Test.

UNIT – II DIFFUSION PROCESSES: FINITE VOLUME METHOD 12

Steady one-dimensional diffusion, Two and three dimensional steady state diffusion problems, Discretization of unsteady diffusion problems – Explicit, Implicit and Crank-Nicholson's schemes, Stability of schemes.

UNIT – III CONVECTION - DIFFUSION PROCESSES: FINITE VOLUME METHOD 12

One dimensional convection – diffusion problem, Central difference scheme, upwind scheme – Hybrid and power law discretization techniques – QUICK scheme. – Assessment of discretization scheme properties.

UNIT – IV INCOMPRESSIBLE FLOW PROCESSES: FINITE VOLUME METHOD 12

Discretization of incompressible flow equations – Stream Function – Vorticity methods - Pressure based algorithms, SIMPLE, SIMPLER, SIMPLEC & PISO algorithms.

UNIT – V TURBULENCE 12

Kolmogorov's Theory - Turbulence - Algebraic Models, One equation model & $k - \varepsilon$, $k - \omega$ models - Standard and High and Low Reynolds number models.

TOTAL: 60 PERIODS

OUTCOMES:

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

CO1 Know the differences between various discretization techniques.

CO2 Learn the finite volume based numerical method for solving diffusion heat transfer problems.

CO3 Learn the finite volume based numerical method for solving convection-diffusion heat transfer problems.

CO4 Understand the discretization of incompressible flow governing equations

CO5 Recognize the impact of various turbulence modelling

REFERENCES:

1. Versteeg and Malalasekera, N, "An Introduction to computational Fluid Dynamics The Finite Volume Method," Pearson Education, Ltd., Second Edition, 2014.
2. Anderson, D.A., Tannehill, J.I., and Pletcher, R.H., "Computational fluid Mechanics and Heat Transfer "Hemisphere Publishing Corporation, New York, USA,1984
3. Subas, V.Patankar, "Numerical heat transfer fluid flow", Hemisphere Publishing Corporation, 1980.

4. Tapan K. Sengupta, "Fundamentals of Computational Fluid Dynamics" Universities Press, 2011.
5. Muralidhar, K., and Sundararajan, T., "Computational Fluid Flow and Heat Transfer", Narosa Publishing House, 2nd edition, 2003.

CO – PO MAPPING:

CO	PO					
	1	2	3	4	5	6
1	3	-	3	3	2	-
2	3	-	3	3	2	-
3	3	-	3	3	2	-
4	1	-	3	3	2	-
5	1	-	3	3	2	-
Avg	2.2	-	3	3	2	-

EY3211 ANALYSIS AND SIMULATION LABORATORY FOR ENERGY ENGINEERING

L	T	P	C
0	0	4	2

OBJECTIVE:

Learn the simulation analysis software(s) and get expertise with the computational procedure to study the behavior of various thermal energy systems and numerically solve the problems related to heat transfer & fluid flow

LIST OF EXPERIMENTS

1. Conduction heat transfer analysis
2. Convection heat transfer analysis – Internal flow &Velocity boundary layer
3. Radiation heat transfer analysis
4. Analysis of flow through a pipe
5. Boiling heat transfer analysis
6. Condensation heat transfer analysis
7. Heat exchanger analysis – NTU & LMTD method
8. Critical radius of insulation
9. Nozzle/Diffuser Analysis
10. Lumped heat transfer analysis
11. Simulation of Thermal Power Plant Cycles, Configuration, Instrumentation and Controls

TOTAL: 60 PERIODS

OUTCOMES:

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

CO1 Use modern software tools to simulate, analyze and optimize any thermal energy system

CO2 Investigate the various process parameters influencing the performance of the thermal system

CO3 Illustrate the outcomes in brief containing the details of the domain analyzed in the form of a detailed report

CO – PO MAPPING:

CO	PO					
	1	2	3	4	5	6
1	3	1	3	3	3	3
2	1	1	3	3	2	3
3	3	3	3	3	3	3
Avg	**2.3**	**1.7**	**3**	**3**	**2.7**	**3**

EY3212 SUMMER INTERNSHIP

L	T	P	C
0	0	0	2

OBJECTIVE:

To understand, learn and apply the principles and practices of Energy Conservation in Industrial Utilities through hands on training.

GUIDELINES:

- Each student has to undergo Industrial training for a minimum period of four weeks during the upcoming summer vacation (i.e., between II and III Semester).
- The Internship has to be undergone continuously for the entire period.
- The Internship must be carried out in an energy intensive industry (HT Consumer)
- The End Semester Examination must be conducted at the start of III Semester.
- The mark will be based on the project report (Introduction; Project or Training details; Techno Economics; Discussion; and Conclusion) and their presentation followed by oral examination on the same by internal examiner.

TOTAL: -

OUTCOMES:

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

CO1 Evaluate Specific Energy Consumption of industrial utilities

CO2 Suggest measures for energy conservation in industrial utilities.

CO3 Prepare and present a detailed project report professionally

CO – PO MAPPING:

CO	PO					
	1	2	3	4	5	6
1	3	3	3	3	3	3
2	3	3	3	3	3	3
3	3	3	3	3	3	3
Avg	3	3	3	3	3	3

EY3311 **PROJECT WORK – I**

L	T	P	C
0	0	12	6

OBJECTIVE:

The main learning objective of this course is to prepare the students for identifying a specific problem for the current need of the society and or industry, through detailed review of relevant literature, developing an efficient methodology to solve the identified specific problem.

GUIDELINES:

- Each PG student shall work individually on a selected specific topic in the area of **ENERGY** which shall be approved by the Head of the Division under the supervision of a Faculty Member (Guide / Supervisor) who is familiar in the selected specific topic. The selected specific topic maybe theoretical and or experimental and or simulation and or case study. The students' Project Work – Phase I shall be evaluated through Internal Examination and End Semester Examination.
- The Internal Examination must be conducted periodically (Zeroth, First, Second and Third) through Project Work Review Presentation Meetings followed by questions from the panel of Review Committee Members comprising of two expert faculty members and a project coordinator.
- At the end of the semester, a detailed report on the work done by the PG student must be submitted with the approval from the Guide/Supervisor and the Review Committee Members. The Project Work – Phase I Report must contain the Introduction with clear definition along with detailed review of relevant literature on the selected specific problem; an efficient methodology to solve the selected specific problem along with necessary hypothesis and or experimental setup and or simulation and or case study for carrying out the research project work along with preliminary results; discussions, relevant conclusions and future direction along with specified references.
- The End Semester Examination must be conducted through Project Work Presentation followed by questions from the panel of Examiners comprising an External Examiner and Project Coordinator as Internal Examiner.

TOTAL: 180 PERIODS

OUTCOMES:

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

CO1 Demonstrate a sound technical knowledge in their selected project topic.

CO2 Select and identify the problem statement along with scope and boundary; assimilate detailed review of relevant literature; formulate an efficient methodology to solve the selected specific problem.

CO3 Propose engineering design solutions to complex problems using a systematic approach.

CO – PO MAPPING:

CO	PO					
	1	2	3	4	5	6
1	3	3	3	3	3	3
2	3	3	3	3	3	3
3	3	3	3	3	3	3
Avg	3	3	3	3	3	3

EY3411	PROJECT WORK - II	L	T	P	C
		0	0	24	12

OBJECTIVE:

The main learning objective of this course is to prepare the students for solving the specific problem for the current need of the society and or industry, through the formulated efficient methodology, and to develop necessary skills to critically analyse and discuss in detail regarding the project results and making relevant conclusions.

GUIDELINES:

- The student may continue to work on the Project Work – I's selected topic as per the formulated efficient methodology under the same Faculty Member (Guide/Supervisor). The students' Project Work – II shall be evaluated through Internal Examination and End Semester Examination.
- The Internal Examination must be conducted periodically (First, Second and Third) through Project Work Review Presentation Meetings followed by questions from the panel of Review Committee Members comprising of two expert faculty members and a project coordinator.
- At the end of the semester, a detailed report on the work done by the PG student must be submitted with the approval from the Guide/Supervisor and the Review Committee Members. The Thesis (Project Work – II Report) must contain the Introduction with clear definition along with detailed review of relevant literature on the selected specific problem; an efficient methodology to solve the selected specific problem along with necessary theoretical hypothesis and or experimentation and or simulation and or case study for carrying out the research project work along with complete results with critical analysis and detail discussions, followed by relevant conclusions, along with specified references.
- The End Semester Examination must be conducted through Project Work Presentation followed by questions from the panel of Examiners comprising an External Examiner and Project Coordinator as Internal Examiner.

TOTAL: 360 PERIODS

OUTCOMES:

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

CO1 Demonstrate a sound technical knowledge in their selected project topic.

CO2 Propose product design & development solutions to complex problems using a systematic approach.

CO3 Demonstrate the knowledge, skills and attitudes of a professional engineer to take up any challenging practical problem in the field of engineering design and find optimum solutions to it.

CO – PO MAPPING:

CO	PO					
	1	2	3	4	5	6
1	3	3	3	3	3	3
2	3	3	3	3	3	3
3	3	3	3	3	3	3
Avg	**3**	**3**	**3**	**3**	**3**	**3**

EY3001	BIO ENERGY	L	T	P	C
		3	0	0	3

OBJECTIVE:

To impart knowledge on Combustion of biofuels and to elucidate on various Bio energy Conversion processes.

UNIT – I BIOMASS AVAILABILITY AND CHARACTERIZATION 9

Biomass: types – advantages and drawbacks – Indian scenario – characteristics – carbon neutrality – Assessment Studies - Comparison of biomass with coal : Proximate & Ultimate Analysis - Thermo Gravimetric Analysis – Differential Thermal Analysis – Differential Scanning Calorimetry

UNIT – II COMBUSTION 9

Perfect, complete, and incomplete combustion – computation of stoichiometric air - equivalence ratio – fixed Bed and fluid Bed combustion - fuel and ash handling systems – steam cost comparison with conventional fuels – Cofiring - Cogeneration

UNIT – III THERMOCHEMICAL CONVERSION OF BIOMASS 9

Gasification, Pyrolysis, Carbonization : Chemistry - Types – Comparison – process governing parameters – typical yield rates - Applications – Economics

UNIT – IV BIO CHEMICAL CONVERSION OF BIOMASS 9

Biomethanation: Possible feed stocks - Chemistry - Types – Comparison – process governing parameters – typical yield rates - Applications – Economics - Biogas plant design. Fermentation - Alcoholic fuels (methanol and ethanol) from biomass.

UNIT – V MECHANICAL CONVERSION OF BIOMASS 9

Straight Vegetable Oil: Transesterification - Biodiesel from Algae – Applications. Briquetting and Pelletization: Types – Comparison – Process Governing Parameters - Economics.

TOTAL: 45 PERIODS

OUTCOMES:

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

CO1 Estimate the surplus biomass availability of any given area

CO2 Determine and compare the cost of steam generation from biofuels with that of coal and petroleum fuels

CO3 Analyse the influence of process governing parameters in thermochemical conversion of biomass

CO4 Design a biogas plant for a variety of biofuels

CO5 Synthesize liquid biofuels for power generation from biomass

REFERENCES:

1. Sjaak van Loo, Jaap Koppejan, “The Handbook of Biomass Combustion and co-firing”, Routledge, First Edition, 2008.
2. David C. Dayton, Thomas D. Foust, “Analytical Methods for Biomass Characterization and Conversion”, Elsevier, 2019 (ebook).
3. D.D. Hall and R.P. Grover, “Biomass Regenerable Energy”, John Wiley, First Edition, 1987.
4. Chakraverthy A, “Biotechnology and Alternative Technologies for Utilization of Biomass or Agricultural Wastes”, Oxford & IBG publishing Co. Ltd., First Edition, 1989.
5. Samir K. Khanal, “Bioenergy and Biofuel from Biowastes and Biomass”, ASCE, 2010.

CO – PO MAPPING:

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1	2	3	-	-	3	2
2	2	3	-	-	3	2
3	2	3	-	-	3	3
4	2	3	-	-	3	3
5	2	3	-	-	3	3
Avg	**2**	**2**	**-**	**-**	**3**	**2.6**

EY3002 **WIND ENERGY**

L	T	P	C
3	0	0	3

OBJECTIVE:

To impart knowledge on fundamentals of wind energy and wind turbine power generation system

UNIT – I WIND ENERGY FUNDAMENTALS & RESOURCE ASSESSMENT 9

Wind Energy Basics, Wind Speeds and scales, Terrain, Roughness, Wind Mechanics, Power Content, Class of wind turbines, Atmospheric Boundary Layers, Turbulence. Instrumentation for wind measurements, Wind data analysis, tabulation, Wind resource estimation, Betz's Limit, Turbulence Analysis

UNIT – II WIND TURBINE AERODYNAMICS AND CLASSIFICATION 9

Airfoil terminology, Blade design, Rotor performance and dynamics, Balancing technique (Rotor & Blade), Materials of Construction, Types of loads; Sources of loads Vertical Axis Type, Horizontal Axis, Constant Speed Constant Frequency, Variable speed Variable Frequency, Up Wind, Down Wind, Stall Control , Pitch Control, Gear Coupled Generator type, Direct Generator Drive /PMG/Rotor Excited Sync Generator

UNIT – III GEAR COUPLED WIND TURBINE POWER GENERATION SYSTEM 9

Electronics Sensors / Encoder /Resolvers, Wind Measurement : Anemometer & Wind Vane, Grid Synchronization System, Soft Starter, Switchgear [ACB/VCB], Transformer, Cables and assembly, Compensation Panel, Programmable Logic Control, UPS, Yaw & Pitch System : AC Drives, Safety Chain Circuits, Generator Rotor Resistor controller (Flexi Slip), Differential Protection Relay for Generator, Battery / Super Capacitor Charger & Batteries / Super Capacitor for Pitch System, Transient Suppressor / Lightning Arrestors, Oscillation & Vibration sensing

UNIT – IV DIRECT ROTOR COUPLED WIND TURBINE POWER SYSTEMS 9

Excited Rotor Synch. Generator / PMG Generator, Control Rectifier, Capacitor Banks, Step Up / Boost Converter (DC - DC Step Up), Grid Tied Inverter, Power Management, Grid Monitoring Unit (Voltage and Current), Transformer, Safety Chain Circuits

UNIT – V MODERN WIND TURBINE CONTROL & MONITORING SYSTEM 9

Details of Pitch System & Control Algorithms, Protections used & Safety Consideration in Wind turbines, Wind Turbine Monitoring with Error codes, SCADA & Databases: Remote Monitoring and Generation Reports, Operation & Maintenance for Product Life Cycle, FACTS control & LVRT & New trends for new Grid Codes – Policies – Reengineering of old blades – Life cycle analysis.

TOTAL: 45 PERIODS

OUTCOMES:

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

CO1 Perform Wind resource estimation and Wind data analysis
CO2 Design Airfoil based Wind Turbine blades and analyze the rotor performance
CO3 Comprehend the various components used in gear coupled wind turbine power systems
CO4 Identify suitable generators and power electronic components for wind power systems
CO5 Develop algorithms for Wind turbine control and monitoring systems

REFERENCES:

1. J. F. Maxwell, J. G. McGowan, and A. L. Rogers, "Wind Energy Explained – Theory, Design, and Applications", John Wiley & Sons, 2010
2. M. Hansen, Aerodynamics of Wind Turbines, Routledge, 2015.

3. T. Burton, D. Sharpe, N. Jenkins and E. Bossanyi, "Wind energy Handbook", John Wiley & Sons, 2001
4. S. Heier, "Grid Integration of Wind Energy Conversion Systems", Wiley, 2014.
5. F. M. Vanek and L. D. Albright, "Energy Systems Engineering – Evaluation & Implementation", McGraw Hill Professional, 2016.
6. John D Sorensen & Jens N Sorensen," Wind Energy Systems", Woodhead Publishing Ltd, 2011
7. NIWE: Wind Energy Resources Survey in India.
8. David A. Spera, "Wind Turbine Technology: Fundamental Concepts in Wind Turbine Engineering", ASMS Press, Second Edition, 2009.

CO – PO MAPPING:

CO	PO					
	1	2	3	4	5	6
1	2	3	-	3	3	3
2	3	3	-	3	3	2
3	2	3	-	1	3	2
4	2	3	-	1	3	2
5	2	3	-	3	3	2
Avg	**2.2**	**3**	-	**2.2**	**3**	**2.2**

EY3003	SOLAR ENERGY	L	T	P	C
		3	0	0	3

OBJECTIVE:

To impart knowledge on the fundamentals of solar radiation, working principle of different types of solar thermal collectors, Solar PV system and Energy Storage

UNIT – I FUNDAMENTALS OF SOLAR RADIATION 9

Solar Spectrum - Solar Radiation Extra-terrestrial Characteristics – Solar Constant - Solar Angles – Sun path diagram - Solar Radiation interaction with atmosphere – Air mass – Rayleigh and Mie Scattering –- Measurement of Solar Radiation and Sun shine – Irradiation – Insolation – Peak Sunshine Hours - Intensity of Sun Light on an arbitrary surface at any time.

UNIT – II SOLAR THERMAL TECHNOLOGY 9

Thermodynamic analysis & Optical Properties of various solar thermal collectors – Flat Plate Collectors – Evacuated Tube collectors – Parabolic Trough – LFR - Parabolic Dish – Scheffler Dish – Heliostats – Tracking systems for thermal collectors - Necessity of Storage of Solar Energy – Thermal Energy Storage – Sensible and Latent Heat Storage

UNIT – III SOLAR PHOTOVOLTAIC TECHNOLOGY 9

Fundamentals of Photovoltaic conversion – Solar Cell – Types - IV Characteristics – PV Module – PV array – Solar PV Power systems Design – Stand Alone System – Grid Connected System – Hybrid Systems – Power Electronics – MPPT – PV market analysis and economics of SPV systems – Solar PV energy Storage - Compressed air energy storage – Pumped Hydro energy storage – Batteries – Green Hydrogen.

UNIT – IV SOLAR ENERGY APPLICATIONS 9

Principle, Types, Construction, Working, Economics, Merits and Demerits of:
Solar Cookers – Solar Dryers – Solar Desalination – Solar Furnace – Solar Cooling – Solar Chimney – Solar Water Pumps - Solar Street Light – Solar Vehicles – Building Adaptive system - BIPV systems – Solar Thermal Power Plants

UNIT – V SOLAR PASSIVE ARCHITECTURE 9

Thermal comfort - bioclimatic classification – passive heating concepts: direct heat gain - indirect heat gain - isolated gain and sunspaces - passive cooling concepts: evaporative cooling - Radiative cooling- application of wind, water and earth for cooling; shading - paints and cavity walls for cooling – roof radiation traps - earth air-tunnel – energy efficient landscape design - thermal comfort

TOTAL: 45 PERIODS

OUTCOMES:

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

CO1 Perform Solar Radiation Resource assessment on a particular site.
CO2 Design a solar thermal collectors for required applications
CO3 Capacity prediction of SPV Modules and accessories for any given application
CO4 Identify a relevant technology for harnessing solar energy for any desired application
CO5 Suggest suitable technologies for passive solar heating and cooling of Buildings

REFERENCES:

1. S. P. Sukhatme, J K. Nayak, “Solar Energy”, McGraw Hill, New Delhi, Fourth Edition, 2017.
2. John A. Duffie, William A. Beckman, “Solar Engineering of Thermal Processes”, John Wiley & Sons, 2013
3. Chetan Singh Solanki, “Solar Photovoltatics – Fundamentals, Technologies and Applications”, PHI Learning Private limited, 2011

4. HP Garg and J Prakash, “Solar Energy: Fundamentals and Applications”, Tata McGraw Hill, 2010.
5. Robert Huggins, “Energy Storage: Fundamentals, Materials and Applications”, 2nd edition, Springer, 2015
6. David A. Bainbridge, Ken Haggard, Kenneth L. Haggard, “Passive Solar Architecture: Heating, Cooling, Ventilation, Daylighting, and More Using Natural Flows”, Chelsea Green Publishing, 2011.

CO – PO MAPPING:

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1	3	3	-	3	3	3
2	3	3	-	3	3	3
3	3	3	-	3	3	3
4	1	3	-	3	3	3
5	2	3	-	3	3	3
Avg	**2.4**	**3**	**-**	**3**	**3**	**3**

EY3004 HYDRO ENERGY

	L	T	P	C
	3	0	0	3

OBJECTIVE:

The objective is to impart comprehensive knowledge and understanding of various renewable energy sources, including hydro energy, OTEC system, tidal energy conversion systems, and wave energy converters. Specifically, to learn about their fundamentals, various types of hydro projects, components used in hydro power projects, construction and working of different types of OTEC systems and the different types of tidal energy conversion systems and wave energy converters.

UNIT – I HYDRO POWER – BASICS 9

Overview of Conventional Hydro Electric Power Plant - Small, Micro & Mini Hydro Power Plants – Government Hydro Power Policies – Environmental Norms - Site Selection - Types of Survey – Types of flow measurement devices – Flood – Discharge estimation: Kripitech formula, Dickens Formula, Hydrograph – Pumped Hydro Power Plant – Construction and Working

UNIT – II COMPONENTS OF HYDRO POWER STATION 9

Major components of Hydropower Station: Dam - Details of desilting tank - Storage & Balancing reservoir - Pen Stock, Pipe Line & Tunneling - Surge Tank - Valve House – Turbines - Generator - Protection & Control equipment - Governors - Earthing and Grounding – Power Factor – Switchyards – Power Transformer

UNIT – III OCEAN THERMAL ENERGY CONVERSION 9

OTEC: principle - types – efficiency – present status – limitations - environmental impacts

UNIT – IV TIDAL ENERGY CONVERSION 9

Tides: formation – types – efficiency – present status – limitations – environmental impacts

UNIT – V WAVE ENERGY 9

Waves: formation – types – efficiency – present status – limitations – environmental impacts

TOTAL: 45 PERIODS

OUTCOMES:

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

CO1 Perform SWOT analysis for a typical Hydro power project
CO2 Detail the various components used in the Hydro power projects
CO3 Elucidate the pros and cons of an OTEC plant
CO4 Propose a suitable tidal energy scheme for the requirement
CO5 Analyse the pros and cons of wave energy converters

REFERENCES:

1. P.K.Nag, “Power Plant Engineering”, McGraw Hill, Fifth Edition, 2021.
2. Nancy Dickmann, “Energy from Water: Hydroelectric, Tidal and Wave Power”, Crabtree Publishing Company, 2016
3. P.S. Nigam, “Handbook of Hydro Electric Engineering”, Nem Chand & Bros, 2008.
4. B H Khan, “Non-Conventional Resources”, McGraw Hill, Third Edition, 2016.
5. D.P.Kothari, K.C.Singal, Rakesh Ranjan, “Renewable Energy Sources and Emerging Technologies”, PHI, 2022.

CO – PO MAPPING:

CO	PO					
	1	2	3	4	5	6
1	3	3	-	-	3	3
2	3	3	-	-	3	3
3	3	3	-	-	3	3
4	3	3	-	-	3	3
5	3	3	-	-	3	3
Avg	3	3	-	-	3	3

EY3053 POLYGENERATION SYSTEMS

	L	**T**	**P**	**C**
	3	**0**	**0**	**3**

OBJECTIVE

To gain knowledge and expertise in polygeneration systems, including energy systems integration, basic processes and components, performance estimation, methods, and applications in buildings and industries, for promoting sustainable development.

UNIT I ENERGY SYSTEMS AND INTERGRATION 9

Energy and Sustainability indicators – Steady flow devices – Thermodynamic approach – System integration – Polygeneration layout – Polygeneration Fuels – Fossil Fuels, Renewable energy fuels and Hybrid fuels – Products of Polygeneration

UNIT II PROCESSES AND COMPONENTS OF POLYGENERATION SYSTEMS 9

Process and components in IC Engines, Steam Cycles, Organic Rankine Cycles, Gas power Cycles, Combined Cycles, Fuel Cells, Electric and Heat driven heat pump and refrigeration cycles; Renewable energy based systems – Energy Storage Systems – Electric and Hydrogen based systems.

UNIT III PERFORMANCE EVALUATION OF POLYGENERATION SYSTEMS 9

Natural gas, biomass and solar based polygeneration systems – Effective first law and Exergy efficiency – optimum design for plant and operation – Environmental benefits – Thermoeconomic analysis of polygeneration systems

UNIT IV POLYGENERATION SYSTEMS IN BUILDINGS 9

Energy in buildings – Space heating and cooling, Energy Demand, Storage Options – Net Zero Buildings – Fuel based polygeneration systems – IC Engines, Fuel Cell – Solar based polygeneration systems - Case Studies

UNIT V POLYGENENRATION SYSTEMS IN INDUSTRIES 9

Polygeneration concepts in Industries – Evaluation – Coal based Polygeneration Systems – Renewable energy polygeneration systems – Low grade industrial waste heat based polygeneration systems- Case Studies

TOTAL: 45 PERIODS

OUTCOMES

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

CO 1 Analyze the energy systems and their integration for sustainable development
CO 2 Apply the basic processes and components of polygeneration systems
CO 3 Estimate the performance of various polygeneration systems
CO 4 Apply various methods of polygeneration systems and its application in buildings
CO 5 incorporate and analysis polygeneration systems in Industries

REFERENCES

1. Ibrahim Dincer and Yusulf bicer, “Integrated Energy Systems for multigeneration”, Elesvier Ltd, 2020
2. Franceso Calise, Maasimo Daccadia, Laura Vanoli and Maria Vicidomini, “Polygeneration systems – Deign, Process and echnlogies”, Academic Press, 2022

3. Majid Amidpour, Mohammad Hasan Khoshgoftar Manesh, "Cogeneration and Polygeneration Systems", Elesevier Science, 2020
4. Yang Chen, "Optimal Design and Operation of Energy Polygeneration Systems", MIT Press, 2013
5. Cristina Gil de Moya, Carl-Johan Fogelholm, "Technoeconomic Assessment of Polygeneration Systems", Universitat Politècnica de Catalunya. Escola Tècnica Superior d' Enginyeria Industrial de Barcelona, 2008

CO – PO MAPPING:

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1	3	1	2	-	3	3
2	3	1	2	-	2	3
3	2	2	2	-	2	2
4	3	2	3	-	3	3
5	2	3	2	-	2	3
Avg.	**2.6**	**1.8**	**2.2**	-	**2.4**	**2.8**

EY3054 WASTE TO ENERGY CONVERSION SYSTEMS **L T P C**
3 0 0 3

OBJECTIVE

To acquire comprehensive knowledge and understanding of bio-energy systems, including the interpretation of various types of wastes for energy generation, biomass pyrolysis process and its applications, various types of biomass gasifiers and their operations, biomass combustors and their applications in energy generation, and the principles and features of bio-energy systems.

UNIT I INTRODUCTION - ENERGY FROM WASTE **9**

Introduction to energy from waste: characterization and classification of waste as fuel – Agro-based, forest residues, industrial waste, Municipal solid waste; Conversion devices – Incinerators, gasifiers, digestors

UNIT II COMBUSTION **9**

Densification of solids, Biomass stoves, Fixed bed combustors, Types, inclined grate combustors, Fluidized bed combustors, Efficiency improvement of power plant and energy production from waste plastics

UNIT III GASIFICATION **9**

Gasifiers – Fixed bed system – Downdraft and updraft gasifiers – Fluidized bed gasifiers – Design, construction and operation – Thermal Applications – Syngas production, Gasifier engine arrangement and electrical power – Equilibrium and kinetic consideration in gasifier operation.

UNIT IV PYROLYSIS **9**

Pyrolysis – Types, slow fast – Manufacture of charcoal – Methods - Yields and application – Manufacture of pyrolytic oils and gases, yields and applications.

UNIT V OTHER PROCESS **9**

Energy production from organic wastes through anaerobic digestion and fermentation, introduction to microbial fuel cells - Energy production from wastes through fermentation and transesterification - Cultivation of algal biomass from wastewater and energy production from algae

TOTAL: 45 PERIODS

OUTCOMES

CO1 Understand the various types of wastes from which energy can be generated
CO2 Gain knowledge on biomass pyrolysis process and its applications
CO3 Develop knowledge on various types of biomass gasifiers and their operations
CO4 Gain knowledge combustors and its applications on generating energy
CO5 Understand the principles of bio-energy systems and their features

REFERENCES

1. Rogoff, M.J. and Screve, F., "Waste-to-Energy: Technologies and Project Implementation", Elsevier Store, 2011
2. Young G.C., "Municipal Solid Waste to Energy Conversion processes", John Wiley and Sons, 2010
3. Mateusz Suzbel and Mariusz Filipowicz, Biomass in Small Scale Energy Applications, CRC Press, 2019
4. EL-Halwagi, M.M., "Biogas Technology- Transfer and Diffusion", Elsevier Applied Science, 1986

CO – PO MAPPING:

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1	2	3	-	-	3	2
2	2	3	-	-	3	2
3	2	3	-	-	3	3
4	2	3	-	-	3	3
5	2	3	-	-	3	3
Avg	**2**	**2**	**-**	**-**	**3**	**2.6**

EY3055 ENERGY CONSERVATION IN BUILDINGS L T P C
3 0 0 3

OBJECTIVE

To incorporate the knowledge of the green buildings, methods to evaluate the thermal performance of buildings.

UNIT I INTRODUCTION 9

Climate and Building, Historical perspective, Aspects of green building design – Sustainable Site, Water, Energy, Materials and IEQ, ECBC Standards, GRIHA, LEED and Wellness Standards

UNIT II LANDSCAPE AND BUILDING ENVELOPES 9

Energy efficient Landscape design – Microclimate, Shading, Arbors, Windbreaks, Xeriscaping, Building envelope – Thermal comfort, Psychrometry, Comfort indices, Thermal Properties of Building Materials – Thermal Resistance, Thermal Time Constant (TTC), Diurnal Heat Capacity (DHC), Thermal Lag, Decrement Factor, Effect of Solar Radiation – Sol-air Temperature, Processes of heat exchange of building with environment, Insulation.

UNIT III PASSIVE HEATING AND COOLING SYSTEMS 9

HVAC introduction, Passive Heating – Solar radiation basics, Sun Path Diagram, Direct Heating, Indirect Heating and Isolated heating, Concept of Daylighting, Passive Cooling – Natural Ventilation (Stack and Wind), Evaporative Cooling and Radiative Cooling.

UNIT IV THERMAL PERFORMANCE OF BUILDINGS 9

Heat transfer due to fenestration/infiltration, Calculation of Overall Thermal Transmittance, Estimation of building loads: Steady state method, network method, numerical method, correlations, Thermal Storage integration in buildings, Computer packages for carrying out thermal design of buildings and predicting performance.

UNIT V RENEWABLE ENERGY IN BUILDINGS 9

Introduction of renewable sources in buildings, BIPV, Solar water heating, small wind turbines, stand-alone PV systems, Hybrid system – Economics.

TOTAL: 45 PERIODS

OUTCOMES:

Upon completion of this course, the students will

CO 1 Be familiar with climate responsive building design and basic concepts
CO 2 Know the basic terminologies related to buildings
CO 3 be Able to apply the passive (air) conditioning techniques in buildings.
CO 4 Evaluate the performance of buildings
CO 5 Gets acquainted with Renewable energy systems in buildings

REFERENCES

1. Baruch Givoni: "Climate considerations in building and Urban Design", John Wiley & Sons, 1996.
2. Jakhar O P, "Energy Conservation in Buildings", Khanna Publishers, 1st Edition, 2020.
3. Jan F. Kreider, Peter S. Curtiss, Ari Rabl, "Heating and Cooling of buildings: Design for Efficiency", CRC Press, Second Edition, 2010.
4. Ana-Maria Dahija, "Energy Efficient Buildings Design", Springer, 2020
5. J.L. Threlkeld, "Thermal Environmental Engineering", Prentice Hall, 1970

CO – PO MAPPING:

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1	1	3	2	-	1	2
2	2	1	2	-	2	2
3	3	1	3	-	2	2
4	3	2	3	-	2	2
5	2	3	1	-	1	2
Avg.	**2.2**	**2**	**2.2**	**-**	**1.6**	**2**

EY3056 INDUSTRIAL REFRIGERATION AND AIR CONDITIONING SYSTEMS L T P C
3 0 0 3

OBJECTIVE

To edify the thermodynamic analysis of Refrigeration cycles, methods for evaluating the thermal load for Industrial and commercial applications and various refrigeration and HVAC systems used in the industries.

UNIT I REFRIGERATION CYCLES – ANALYSIS 9

Unit of refrigeration – Classification of Refrigerants, Refrigerant properties, Environmental Impact-Montreal / Kyoto protocols - Development of Vapor Compression Refrigeration Cycle, Heat pumps – Multi-pressure System, Cascade Systems - Analysis. Non-Compression based Systems: Vapor Absorption Systems-Aqua Ammonia & Li-Br Systems, Steam Jet, Refrigeration Thermo Electric Refrigeration

UNIT II AIR CONDITIONING PROCESSES and SYSTEMS 9

Moist Air properties, use of Psychrometric Chart, Various Psychrometric processes, Air Washer, Adiabatic Saturation. Summer and winter Air conditioning, Enthalpy potential and its insights. Types of Air conditioning systems – Unitary type Units, Variable air Volumes, Central Plant, District Cooling Systems - Thermal distribution systems – Single, multi zone systems, terminal reheat systems, Dual duct systems.

UNIT III THERMAL LOAD ESTIMATION 9

Thermal comfort – Design conditions – Solar Radiation-Heat Gain through envelopes – Infiltration and ventilation loads – Internal loads – Procedure for heating and cooling load Estimation in Buildings – Load estimation for Specific Industrial process

UNIT IV SYSTEM COMPONENTS 9

Compressor- Types, performance, Characteristics, Types of Evaporators & Condensers and their functional aspects, Expansion Devices, and their Behaviour with fluctuating load, cycling controls, other components such as Accumulators, Receivers, Oil Separators, Strainers, Driers, Check Valves, Solenoid Valves Defrost Controllers, etc. Air Handling Units and Fan Coil units – Control of temperature, humidity, air flow and quality.

UNIT V HVAC & R SYSTEM IN INDUSTRIES 9

Plant layout, Working fluids, Refrigeration Cycles and their control in Automobiles, Textile, Pharmaceutical, Dairy and Food Processing Industries

OUTCOMES:

Upon completion of this course, the students will

CO 1 Be familiar with refrigeration cycles and systems concepts.
CO 2 Know the basic thermodynamic process and systems of air conditioning.
CO 3 Be Able to estimate the heating and cold load for the building or industrial process.
CO 4 Know about the different components used in the units.
CO 5 Gets acquainted with HVAC&R systems in various industries.

REFERENCES

1. Arora, C.P., “Refrigeration and Air conditioning”, McGraw Hill, 3rd Ed., 2010.
2. Dossat R.J., “Principles of refrigeration”, John Wiley, 2001.
3. Ibrahim Dincer, “Refrigeration Systems and Applications”, John Wiley & Sons, 2017.
4. Stoecker W.F., “Industrial Refrigeration”, McGraw-Hill Book Company, 1998
5. ASHRAE, “Fundamentals, Refrigeration, Systems and equipment”, 4 volumes-ASHRAE Inc. 2020,21,22 & 23.
6. Carrier Air Conditioning Co., “Handbook of Air Conditioning Systems design”, McGraw Hill, 1985.
7. Jones, “Air Conditioning Engineering”, Edward Amold pub., 2001.

CO – PO MAPPING:

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1	3	-	3	-	2	3
2	2	-	2	-	2	3
3	3	-	2	-	2	2
4	3	-	2	-	2	3
5	2	-	2	-	2	3
Avg.	**2.6**	**-**	**2.2**	**-**	**2**	**2.8**

EY3064 DESIGN AND ANALYSIS OF TURBO MACHINES

	L	T	P	C
	3	0	0	3

OBJECTIVE:

The objective of this course is to provide in-depth knowledge to students on energy transfer process, components, and performance of various turbo machines.

UNIT – I INTRODUCTION 9

Types and applications of Turbomachines – Application of Dimensional analysis to Turbomachnies – Euler's energy transfer equations – Velocity diagrams - Degree of reaction – Specific work and Efficiencies of Turbomachines – Losses in Turbomachines

UNIT – II CENTRIFUGAL AND AXIAL FANS 9

Centrifugal fan – types and stage parameters – performance and point of operation –fans in series and parallel – flow control methods.

Axial fan - stage parameters and types of stages – performance and point of operation – Propellers – slipstream and blade element theory.

UNIT – III CENTRIFUGAL AND AXIAL FLOW COMPRESSORS 9

Centrifugal compressor – configuration and working – slip factor – work input factor – ideal and actual work – pressure coefficient - pressure ratio. Axial flow compressor – geometry and working – velocity diagrams – ideal and actual work – stage pressure ratio – free vortex theory – performance curves and losses.

UNIT – IV AXIAL AND RADIAL FLOW TURBINES 9

Axial flow turbines – impulse and reaction stage parameters – multi-staging – stage loading and flow coefficients. Degree of reaction – losses and efficiencies – performance characteristics

Radial flow turbines – types and stage parameters - stage loading and flow coefficients. Degree of reaction – losses and efficiencies – performance characteristics. Cooling of turbine blades – turbine blade materials.

UNIT – V GAS TURBINE CYCLES AND HYDRAULIC TURBINES 9

Gas Turbine Cycles – open and closed cycle gas turbines – Improvements in Gas Turbine Cycles - Applications Thermodynamic analysis.

Hydraulic turbine – classification and unit quantities – components of hydraulic turbines – design parameters of hydraulic turbines.

TOTAL: 45 PERIODS

OUTCOMES:

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

CO1 Analyze the energy transfer process in thermodynamic systems
CO2 Calculate the performance of centrifugal and axial fans
CO3 Design and analyze centrifugal and axial flow compressor
CO4 Compute and analyze the performance of axial and radial flow turbines
CO5 Predict the performance of gas turbines and thermodynamic energy systems

REFERENCES:

1. Yahya, S.M., "Turbines, Compressor and Fans", Tata McGraw Hill, 4th Edition, 2017
2. Dixon, S.L., "Fluid Mechanics and Thermodynamics of Turbomachinery", Elsevier Butterworth-Heinemann, 7th Edition, 2014

3. Lewis, R.I., “Turbomachinery Performance Analysis,” Arnold / Wiley Publisher, 1st Edition, 1996.
4. Gopalakrishnan. G and Prithvi Raj .D,” A Treatise on Turbomachines”, Scitech Publications (India) Pvt. Ltd., 2nd Edition, 2008.
5. William W. Peng, Fundamentals of Turbomachinery, Wiley, 1st Edition. 2008

CO – PO MAPPING:

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1	3	-	2	2	3	-
2	3	-	2	2	3	-
3	3	-	2	2	3	-
4	3	-	2	2	3	-
5	3	-	2	2	3	-
Avg	**3**	**-**	**2**	**2**	**3**	**-**

EY3065 **DESIGN OF HEAT EXCHANGERS** **L T P C**

3 0 0 3

OBJECTIVE:

To impart knowledge on design aspects, rating, and thermal performance analysis of various types of heat exchangers.

UNIT – I RATING AND PERFORMANCE EVALUATION OF HEAT EXCHANGER 9

Heat Exchanger codes and standards - Heat exchanger design methodology-Basic thermal design theory for recuperators - Ɛ-NTU, P-NTU methods, Mean temperature difference method, Thermal design theory for regenerators- Ɛ-NTU, ΛΠ-NTU.

UNIT – II STRESS AND FAILURE ANALYSIS 9

Material Selection – Mechanical – friction factor – pressure loss – stress in tubes – header sheets and pressure vessels – thermal stresses, shear stresses – Performance failures – Fouling mechanism, Effects of fouling.

UNIT – III DESIGN ASPECTS 9

Heat transfer and pressure loss –flow configuration – effect of baffles – effect of deviations from ideality – design of double pipe - finned tube - shell and tube heat exchangers - simulation of heat exchangers.

UNIT – IV EXTENDED SURFACE HEAT EXCHANGERS 9

Plate fin heat exchangers-Types, Geometric relationship, Rating and Sizing.
Tube fin heat exchangers-Types, Geometric relationship, Heat transfer and pressure drop.

UNIT – V TWO PHASE FLOW HEAT EXCHANGERS AND COOLING TOWERS 9

Liquid - Vapour phase change heat exchanger - Design consideration, pressure drop, thermal performance. Gas-Solid heat exchanger – Design consideration.
Design of surface and evaporative condensers
Cooling tower – Thermal design, Influence of operating variables on performance, Heat and mass balance calculations.

TOTAL: 45 PERIODS

OUTCOMES:

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

CO1 Design a heat exchanger for different applications.
CO2 Understand the significance of stress and failure analysis of heat exchangers
CO3 Understand the design aspects of different heat exchangers.
CO4 Perform rating and sizing of plate and tube heat exchangers
CO5 Design and carryout thermal performance analysis of two-phase flow heat exchangers and cooling towers

REFERENCES:

1. Sadik Kakac, Hongtan Liu, Anchasa Pramuanjaroenkij, “Heat Exchangers Selection, Rating and Thermal Design”, CRC Press, Third Edition, 2012.
2. Ramesh K. Shah, Dušan P. Sekulić,” Fundamentals of heat exchanger design”, John Wiley & Sons, 2003
3. Robert W. Serth, “Process heat transfer principles and applications”, Academic press, Elesevier, 2010

4. T. Kuppan, “Heat exchanger design handbook”, New York: Marcel Dekker, 2009.
5. Arthur. P Frass, “Heat Exchanger Design”, John Wiley & Sons, 1989

CO – PO MAPPING:

CO	PO					
	1	2	3	4	5	6
1	3	-	2	2	3	1
2	3	-	2	2	3	1
3	3	-	2	2	3	1
4	3	-	2	2	3	1
5	3	-	2	2	3	1
Avg	**3**	**-**	**2**	**2**	**3**	**1**

EY3051 ADVANCED POWER PLANT ENGINEERING

	L	T	P	C
	3	0	0	3

OBJECTIVE:

The objective of this course is to enable the students to acquire knowledge on working principle, Energy analysis, Economic analysis, and Environmental impact of different types of power plants. Detail on the role of various utilities in coal based thermal power plants

UNIT – I COAL BASED THERMAL POWER PLANTS 9

Basics of typical power plant utilities – Boilers, Nozzles, Turbines, Condensers, Cooling Towers, Water Treatment and Piping system – steam rate and heat rate – mean temperature of heat addition – Thermodynamic analysis of Rankine cycle, Rankine cycle improvements – Superheat, Reheat, Regeneration, Velocity diagram, Super critical boilers, Pulverized Fuel Boiler, AFBC/PFBC.

UNIT – II DIESEL AND GAS TURBINE POWER PLANTS 9

Otto, Diesel, Dual & Brayton Cycle — Analysis & Optimisation. Diesel power plant – Layout - Performance analysis and improvement – Techniques for starting, cooling and lubrication of diesel engines - Advantages – Limitations.
Brayton cycle – Open and Closed – Improvements - Intercooler, Reheating and Regeneration. Gas Turbines: application - advantages – limitations

UNIT – III CHP AND MHD POWER PLANTS 9

Cogeneration systems – types - heat to power ratio - Thermodynamic performance of steam turbine, gas turbine and IC engine-based cogeneration systems – Polygeneration - Binary Cycle - Combined cycle.
MHD – Open cycle and closed cycle- Hybrid MHD & Steam power plants

UNIT – IV HYDROELECTRIC & NUCLEAR POWER PLANTS 9

Hydroelectric Power plants – Classifications - essential elements – pumped storage systems – micro and mini hydel power plants.
General aspects of Nuclear Engineering, Components of nuclear power plants -Types of Fuel, Moderators, Coolants -Nuclear reactors & types – PWR, BWR, CANDU, Gas Cooled, Liquid Metal Cooled and FBR- Nuclear safety – Environmental issues.

UNIT – V ENERGY, ECONOMIC AND ENVIRONMENTAL ISSUES OF POWER PLANTS 9

Load distribution parameters, connected load, maximum demand, demand factor, average load, load factor, diversity factor, load curve, Comparison of site selection criteria, relative merits & demerits.
Capital & Operating Cost of different power plants, Power tariff types.
Pollution control technologies including Waste Disposal Options for Coal and Nuclear Power Plants

TOTAL: 45 PERIODS

OUTCOMES:

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

CO1 Perform thermodynamic analysis of steam power plant

CO2 Analyse gas power cycles of engines and suggest measures for improving the performance of gas turbine and diesel power plants

CO3 Assess the applicability and performance of a cogeneration system and MHD power plant.

CO4 Identify a suitable type of hydroelectric/nuclear power plant commensurate with the prevailing conditions

CO5 Carryout economic calculation in different power plants and select suitable pollution control technologies.

REFERENCES:

1. Nag, P.K., “Power Plant Engineering”, Tata McGraw Hill Publishing Co Ltd, New Delhi, 2002.
2. Haywood, R.W., “Analysis of Engineering Cycles”, Pergamon Press Oxford, 4th Edition, 2012
3. Wood, A.J., Wollenberg, B.F., “Power Generation, operation and control”, John Wiley, New York,1991.
4. Gill, A.B., “Power Plant Performance”, Butterworths, 1984.
5. Lamarsh, J.R., “Introduction to Nuclear Engineering”, Addison-Wesley, 2nd edition, 1983.
6. Arora and S. Domkundwar, “A Course in Power Plant Engineering”, Dhanpat Rai Publications, 6^{th} edition, 2016

CO – PO MAPPING:

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1	3	2	2	-	3	2
2	3	2	2	-	3	2
3	3	2	2	-	3	2
4	3	2	2	-	3	2
5	3	3	2	-	3	2
Avg	**3**	**2.2**	**2**	**-**	**3**	**2**

EY3057	ENERGY FORECASTING, MODELLING AND PROJECT MANAGEMENT	L	T	P	C
		3	0	0	3

OBJECTIVE:

Gain an understanding of the energy situation at both the national and global levels and utilize available resources to predict and model energy demand while considering current policies.

UNIT – I ENERGY STRUCTURE 9

Role of energy in economic development and social transformation: GDP, GNP and its dynamics – Energy Sources and its Overall demand – Energy Consumption in various sectors and its changing pattern – National & State Level Energy Issues – Status of Renewable Energy: Present and future.

UNIT – II FORECASTING MODEL 9

Qualitative & Quantitative Forecasting Techniques – Regression Analysis – Double Moving Average – Double and Triple Exponential Smoothing – ARIMA model – Delphi technique – Methods for renewable energy forecasting – Application of forecasting to power system management and markets.

UNIT – III OPTIMIZATION MODEL 9

Principles of Optimization – Formulation of Objective Function – Constraints – Multi Objective Optimization – Semi-Empirical Satellite Models, Physically Based Satellite Methods – Satellite–Based Irradiance and Power Forecasting – Concept of Fuzzy Logic.

UNIT – IV PROJECT MANAGEMENT 9

Project Preparation – Feasibility Study – Detailed Project Report – Project Appraisal – Social–cost benefit Analysis – Project Cost Estimation – Project Risk Analysis, Evaluation of Resource Risk in Solar Project Financing.

UNIT – V ENERGY POLICY & SCHEMES 9

Electricity act: Features & its amendments – National Energy Policy – Energy Security – Framework of Central Electricity Authority (CEA), Central Electricity Board (CEB), Central & States Electricity Regulatory Commission (CERC & SERC) – National Power Commission – Tariff and duty of electricity supply in India.
Ministry of New and Renewable Energy (MNRE): ENCON Schemes.

TOTAL: 45 PERIODS

OUTCOMES:

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

CO1 Gain knowledge on the National and Global energy scenario.
CO2 Use various techniques to perform Energy Forecasting and modeling.
CO3 Develop optimization model for energy planning.
CO4 Caliber to execute a project with detailed economic analysis.
CO5 Understand the National and state energy policies.

REFERENCES:

1. George Kariniotakis, “Renewable energy forecasting – From models to applications”, A volume in woodhead publishing series in energy, 2017.
2. William Holderbaum, “Energy Forecasting and Control Methods for Energy Storage Systems in Distribution Networks: Predictive Modelling and Control Techniques”, Springer, 1st Edition, 2023.
3. Jan Kleissl, “Solar Energy Forecasting and Resource Assessment”, Elsevier, 1st Edition, 2013.

4. Dhandapani Alagiri, “Energy Security in India Current Scenario”, The ICFAI University Press, 2006.
5. Spyros G. Makridakis, Steven C. Wheelwright, Rob J. Hyndman, “Forecasting: Methods and Applications, John Wiley & Sons, 4th Edition, 2003.
6. Yang X.S., “Introduction to mathematical optimization: From linear programming to Metaheuristics”, Cambridge, Int. Science Publishing, 2008.
7. Armstrong J.Scott (ed.), “Principles of forecasting: a hand book for researchers and practitioners”, Norwell, Massachusetts: Kluwer Academic Publishers, 1st Edition, 2001.

CO – PO MAPPING:

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1	–	2	3	1	3	–
2	1	–	2	3	1	–
3	3	1	3	3	3	–
4	3	1	3	3	3	3
5	2	3	3	3	3	3
Avg	**2.3**	**1.8**	**2.8**	**2.6**	**2.6**	**3.0**

EY3058 **MODELLING AND ANALYSIS OF ENERGY SYSTEMS**

L	T	P	C
3	0	0	3

OBJECTIVE:

To learn mass and energy balance principles for thermal energy systems, and model/ simulate them to optimize parameters and conduct a detailed economic analysis.

UNIT – I INTRODUCTION 9

Overview of technologies and conventional methods of energy conversion, Workable and optimum systems, Steps in arriving at a workable system, Creativity in concept selection. Energy analysis – energy balance for closed and control volume systems – Modeling overview – levels and steps in model development.

UNIT – II MODELING AND SIMULATION 9

Mathematical modeling, Exponential forms- Method of least squares – Counter flow heat exchanger, Evaporators and Condensers, Effectiveness, NTU, Pressure drop and pumping power. Classes of simulation, flow diagrams, Sequential and simultaneous calculations, Newton-Raphson method- Optimization procedure, mathematical statement of the problem.

UNIT – III OPTIMIZATION TECHNIQUES 9

Dynamic Programming-Geometric Programming - Linear regression analysis, Internal energy and enthalpy, Pressure temperature relationship at saturated conditions. Constrained optimization - Lagrange multipliers, constrained variations - New generation optimization techniques – Genetic algorithm and simulated annealing.

UNIT – IV ENERGY- ECONOMY MODELS 9

Multiplier Analysis - Energy and Environmental Input / Output Analysis - Energy Aggregation – Econometric Energy Demand Modeling - Overview of Econometric Methods - Dynamic programming- Search Techniques - Univariate / Multivariate.

UNIT – V NUMERICAL METHODS 9

Solution strategies for Distributed parameter models: Solving parabolic, elliptic and hyperbolic partial differential equations, Finite element and Finite volume methods.

TOTAL: 45 PERIODS

OUTCOMES:

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

CO1 Apply mass and energy balances for the energy systems
CO2 Perform Simulation and Modeling of typical energy system
CO3 Use the optimization techniques to optimize the energy system.
CO4 Carry out Energy-Economic Analysis for any thermal application.
CO5 Gain knowledge in optimization of Energy system problems.

REFERENCES:

1. W.F.Stoecker: “Design of Thermal Systems”, McGraw Hill, 3rd Edition, 1989.
2. B.K.Hodge: “Analysis and Design of Thermal Systems”, Prentice Hall Inc., 1990.
3. Bejan, A, Tsatsaronis, G and Moran, M., “Thermal Design and Optimization”, John Wiley & Sons, 1996
4. I. J. Nagrath & M.Gopal: “Systems Modelling and Analysis”, Tata McGraw Hill, 2007
5. D.J. Wide: “Globally Optimal Design”, Wiley- Interscience, 1978.
6. Mark E. Davis, “Numerical Methods and Modelling for Chemical Engineers”, John Wiley & Sons, 1984.
7. Stoecker W.F., “Design of Thermal Systems”, McGraw Hill, 2011
8. Yogesh Jaluria, “Design and Optimization of Thermal Systems”, CRC Press INC, 2008

CO – PO MAPPING:

CO	PO					
	1	2	3	4	5	6
1	3	-	-	2	1	-
2	2	-	2	3	2	2
3	3	2	1	2	3	-
4	1	2	-	3	3	2
5	2	1	2	3	3	1
Avg	**2.2**	**1.7**	**1.7**	**2.6**	**2.4**	**1.7**

EY3059	DESIGN AND OPTIMIZATION OF THERMAL ENERGY SYSTEMS	L	T	P	C
		3	0	0	3

OBJECTIVE:
Understand the design principles of any thermal energy system and develop a model to arrive at the optimal solution and study the dynamic behavior of the same with a tradeoff between capital and operating cost using pinch point analysis.

UNIT – I DESIGN CONCEPTS 9

Design Principles, Workable Systems, Optimal Systems, Matching of System Components, modeling overview – levels and steps in model development – Examples of models – curve fitting and regression analysis.

UNIT – II MODELLING AND SYSTEMS SIMULATION 9
Modelling of thermal energy systems – heat exchanger – solar collectors – distillation – refrigeration systems – information flow diagram – solution of set of nonlinear algebraic equations – successive substitution – Newton Raphson method – examples of thermal systems simulation.

UNIT – III OPTIMIZATION 9
Objective function – constrained and unconstrained formulations – necessary and sufficiency conditions. Constrained optimization – Lagrange multipliers, constrained variations, sensitivity analysis – Examples, single and multi–objective problem.

UNIT – IV DETERMINISTIC SEARCH METHODS 9
Non–linear least square minimization – Levenberg-Marquardt, Conjugate gradient algorithm – case studies with deterministic search algorithms.

UNIT – V STOCHASTIC SEARCH METHODS 9
Introduction to random search methods – advantages and disadvantages, Genetic Algorithm. Other advanced algorithms – simulated annealing, Particle Swarm Optimization.

TOTAL: 45 PERIODS

OUTCOMES:
Upon completion of this course, the students will be able to:
CO1 Understand basic design principles of the thermal systems and the type of models suitable for further analysis.
CO2 Carry out the Simulation and Modelling of typical thermal energy systems.
CO3 Analyze the effect of constraints on the performance of thermal energy systems.
CO4 Develop the dynamic analysis of the thermal system with control system feedback arrangement.
CO5 Design, optimize and perform the Energy-Economic Analysis for any thermal system.

REFERENCES:

1. Arora J.S., “Introduction to optimum design”, McGraw Hill, 4th Edition, 2016.
2. Bejan A., George Tsatsaronis, Michael J. Moran, “Thermal Design and Optimization”, Wiley, 1996.
3. Kapur J. N., “Mathematical Modelling”, Wiley Eastern Ltd, New York, 1989.
4. Rao S. S., “Engineering Optimization Theory and Practice”, New Age Publishers, 2010.
5. Stoecker W. F., “Design of Thermal Systems”, McGraw Hill Edition, 2011.
6. Yogesh Jaluria, “Design and Optimization of Thermal Systems”, CRC Press, 2016.
7. Balaji. C, “Thermal System Design and optimization”, Springer, 2021.

CO – PO MAPPING:

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1	1	–	2	3	3	–
2	2	2	2	3	3	1
3	3	–	1	3	3	–
4	1	–	–	2	2	–
5	3	1	2	3	3	2
Avg	**2**	**1.5**	**1.8**	**2.8**	**2.8**	**1.5**

EY3060	**STATISTICAL DESIGN AND ANALYSIS OF EXPERIMENTS**	**L**	**T**	**P**	**C**
		3	**0**	**0**	**3**

OBJECTIVE:

The objective of this course is to provide a holistic view on design of experiments and statistical analysis of experimental data obtained from laboratory or industrial processes.

UNIT – I INTRODUCTION TO RANDOM VARIABLES AND PROBABILITY FUNCTIONS 9

Introduction to probability, Bayes' theorem, Random variables - discrete and continuous, mean and variance, probability distribution functions - Binomial, Poisson, Normal, Weibull, Lognormal, Student-t, Joint probability distributions - marginal and conditional probability, covariance and correlation, bi-variate normal distribution function.

UNIT – II SAMPLING DISTRIBUTIONS AND ANALYSIS OF STATISTICAL INTERVALS 9

Sampling distribution and central limit theorem, General concept of point estimation - unbiased estimators, variance of point estimator, method of point estimation - maximum likelihood, Bayesian estimation, Confidence intervals with known and unknown variance, choice of sample size, guidelines for constructing confidence intervals.

UNIT – III HYPOTHESIS TESTING: SINGLE AND MULTIPLE SAMPLES 9

Statistical hypothesis - tests of statistical hypothesis, General procedure for hypothesis tests
Single sample case: tests on the mean of a normal distribution with known and unknown variance, testing for goodness of fit.
Two sample case: inference on the difference in means of two normal distributions with known and unknown variance, inference on the variances of two normal distributions and population proportions.

UNIT – IV ANALYSIS OF SIMPLE AND MULTIPLE LINEAR REGRESSION MODELS 9

Empirical models, simple linear regression, least square estimators, prediction of new observations and adequacy checking, correlation between parameters.
Multiple linear regression model, prediction of new observations and adequacy checking, multicollinearity.

UNIT – V DESIGN AND ANALYSIS OF SINGLE AND MULTIPLE FACTOR EXPERIMENTS 9

Completely randomized single-factor experiment - analysis of variance, multiple comparisons following ANOVA, residual analysis, and model checking, determining sample size. Random effect model - fixed Vs random effects, ANOVA and variance components. Randomized Complete Block Design (RCBD) - design and statistical analysis, multiple comparisons, residual analysis and model checking, Two-factor factorial experiments, 2^k factorial design - blocking and confounding, fractional replication, response surface methods.

TOTAL: 45 PERIODS

OUTCOMES:

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

CO1 Statistically analyse experimental data obtained from laboratory/industrial process
CO2 Structure engineering decision-making problems as hypothesis tests
CO3 Structure comparative experiments involving two samples as hypothesis tests
CO4 Develop empirical models from engineering data using linear regression, predict future observations, and establish a suitable prediction interval.
CO5 Design and conduct engineering experiments involving single and multiple factor.

REFERENCES:

1. D.C. Montgomery and G.C. Runger, “Applied Statistics and Probability for Engineers”, John Wiley & Sons Inc., 6th Edition, 2016
2. R.A. Johnson, I. Miller and J. Freund, “Probability and Statistics for Engineers”, Prentice Hall Inc., 9th Edition, 2017.
3. R.L. Mason, R.F. Gunst and J.L. Hess, “Statistical Design and Analysis of Experiments – with applications to engineering and science”, John Wiley & Sons Inc., 2nd Edition, 2003
4. B.J. Winer, “Statistical Principles in Experimental Design”, McGraw-Hill, 3rd Edition, 1991
5. A. Dean, D Voss and D. Draguljic, “Design and Analysis of Experiments”, Springer, 2nd Edition, 2017

CO – PO MAPPING:

CO	**PO**					
	1	**2**	**3**	**4**	**5**	**6**
1	3	-	-	-	-	1
2	3	-	-	-	-	1
3	3	-	1	-	-	-
4	3	-	1	-	2	1
5	3	-	1	-	-	-
Avg	**3**	**-**	**1**	**-**	**2**	**1**

EY3061 ENERGY STORAGE TECHNOLOGIES

	L	T	P	C
	3	**0**	**0**	**3**

OBJECTIVE:

To understand the significance and need for various types of energy storage technologies and their uses for real world applications. This course will also enable students to understand the Green Energy Storage of Hydrogen and the challenges associated

UNIT – I INTRODUCTION TO ENERGY STORAGE 9

Necessity of Energy Storage – Types of Energy Storage – Thermal, Mechanical, Chemical, Electrochemical and Electrical - Comparison of Energy Storage Technologies.

UNIT – II THERMAL ENERGY STORAGE SYSTEM 9

Thermal Energy Storage – Types – Sensible, Latent and Thermo-chemical – Sensible Heat Storage - Simple water and rock bed storage system – pressurized water storage system – Stratified System - Latent Heat Storage System - Phase Change Materials – Simple units, packed bed storage units - Other Modern Approaches.

UNIT – III ELECTRICAL ENERGY STORAGE 9

Batteries - Fundamentals and their Working – Battery performance, Charging and Discharging - Storage Density - Energy Density - Battery Capacity - Specific Energy - Memory Effect - Cycle Life - SOC, DOD, SOL - Internal Resistance - Coulombic Efficiency and Safety issues. Battery Types - Primary and Secondary – Lead Acid, Nickel – Cadmium, Zinc Manganese dioxide, Zinc-Air, Nickel hydride, Lithium Ion.

UNIT – IV HYDROGEN ENERGY STORAGE 9

Hydrogen Storage Options – Physical and Chemical Methods - Compressed Hydrogen – Liquefied Hydrogen – Metal Hydrides, Chemical Storage - Other Novel Methods - comparison - Safety and Management of Hydrogen - Applications - Fuel Cells.

UNIT – V ALTERNATE ENERGY STORAGE TECHNOLOGIES 9

Flywheel, Super Capacitors - Pumped Hydro Energy Storage System - Compressed Air Energy Storage System, SMES - Concept of Hybrid Storage – Principles, Methods, and Applications - Electric and Hybrid Electric Vehicles.

TOTAL: 45 PERIODS

OUTCOMES:

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

CO1 Identify the energy storage technologies for suitable applications.
CO2 Apply the appropriate thermal energy storage methods suitably.
CO3 Introduce the concepts, types and working of various batteries.
CO4 Understand the use of Hydrogen as Green Energy for our Future.
CO5 Recognize and choose appropriate methods of Energy Storage and Hybrid Systems.

REFERENCES:

1. Ibrahim Dincer and Mark A. Rosen, “Thermal Energy Storage Systems and Applications”, John Wiley & Sons 2002.
2. James Larminie and Andrew Dicks, “Fuel cell systems Explained”, Wiley publications, 2003.
3. Luisa F. Cabeza, “Advances in Thermal Energy Storage Systems: Methods and Applications”, Elsevier Woodhead Publishing, 2015.

4. Robert Huggins, “Energy Storage: Fundamentals, Materials and Applications”, 2nd edition, Springer, 2015.
5. Ru-shiliu, Leizhang, Xueliang sun, “Electrochemical technologies for energy storage and conversion”, Wiley publications, 2012.

CO – PO MAPPING:

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1	2	3	-	-	3	2
2	2	3	-	-	3	2
3	2	3	-	-	3	3
4	2	3	-	-	3	3
5	2	3	-	-	3	3
Avg	**2**	**2**	**-**	**-**	**3**	**2.6**

EY3052 FUEL CELL TECHNOLOGY

	L	T	P	C
	3	0	0	3

OBJECTIVE:

The major objective of this course is to enhance the knowledge of the students about classifications, construction, working, analysis and applications of fuel cells. This course will also enable students to understand various production and storage techniques of Hydrogen.

UNIT – I OVERVIEW 9

Basics of Fuel Cell Technology - History of Fuel Cells - Fundamentals - Components - Working Principle - Advantages and Limitations - Comparison of Fuel Cell and Battery.

UNIT – II CLASSIFICATION 9

Classification of Fuel Cells - Based on Temperature and Electrolyte - Description and working principles of various types of fuel cells - Components used - Fabrication - Applications - Merits and Demerits of PEMFC, DMFC, PAFC, AMFC, SOFC, MCFC and MFC - Recent Developments and Achievements.

UNIT – III THERMODYNAMIC AND KINETIC ASPECTS OF FUEL CELL 9

Theory - Thermodynamics - Electrochemistry - Energy Conversion Efficiency - Factors that influence Fuel Cell Efficiency - Reaction Kinetics - Electrode Kinetics - Characterization methods - Polarization and Power Density Curves - Fuel Cell Losses - Methods to improve Fuel Cell Performance.

UNIT – IV HYDROGEN PRODUCTION, STORAGE AND SAFETY 9

Hydrogen Salient Characteristics - Physical and Chemical Properties - Hydrogen Economy - Hydrogen Production Methods - Steam Reforming, Electrolysis, Coal Gasification, Biomass Conversion - Biological Methods - Photo dissociation and Photo catalytic Methods - Thermal Methods - Hydrogen Storage - Physical and Chemical Methods - Hydrogen Safety and Risk - Challenges and Management – Codes and Standards.

UNIT – V APPLICATIONS AND CHALLENGES OF FUEL CELL 9

Fuel Cell Applications - Domestic - Industrial - Commercial - Transportation and Stationary Applications - Economics and Environment Analysis - Cost and Safety - Life Cycle Analysis - Future Trends.

TOTAL: 45 PERIODS

OUTCOMES:

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

CO1 Get introduced to the concepts of fuel cell technology.

CO2 Recognize the need for development of various types of fuel cells and their scopes.

CO3 Understand and apply the principles of thermodynamics and reaction kinetics of fuel cell to increase the fuel cell efficiency.

CO4 Gain knowledge on the use of hydrogen as a source of green energy and understand the challenges associated.

CO5 Analyse the cost effectiveness and eco-friendliness of fuel cell technology and understand the impact on the application aspects.

REFERENCES:

1. Aulice Scibioh M. and Viswanathan B, “Fuel Cells – principles and applications’, University Press (India), 2006.

2. Ryan O. H., Suk Won C. and Whiteny C., “Fuel Cell Fundamentals”, John Wiley & Sons, 2016.
3. O’Hayre, R., Cha S. W., Colella W. and Prinz, B., “Fuel Cell Fundamentals”, John Wiley and Sons, 2005.
4. Robert Huggins, Energy Storage: Fundamentals, Materials and Applications, 2nd edition, Springer, 2015
5. Ru-shiliu, Leizhang, Xueliang sun, Electrochemical technologies for energy storage and conversion, Wiley publications, 2012.
6. Barbir F “PEM fuel cells: theory and practice” Elsevier, Burlington, MA 2005.
7. Christopher M A Brett, “Electrochemistry – Principles, Methods and Applications”, Oxford University, 2004.
8. Basu, S., “Fuel Cell Science and Technology”, Springer, 2007.

CO – PO MAPPING:

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1	2	3	-	-	3	1
2	2	3	-	-	3	1
3	2	3	-	-	3	1
4	2	3	-	-	3	1
5	2	3	-	-	3	1
Avg	**2**	**3**	**-**	**-**	**3**	**1**

EY3062 **HYDROGEN GENERATION, STORAGE AND APPLICATION**

L	T	P	C
3	0	0	3

OBJECTIVE:

To understand the importance of Hydrogen as the Green energy and its need for Sustainable Growth. This course will also enable students to understand various productions, storage, utilization techniques, codes, standards of Hydrogen.

UNIT – I INTRODUCTION TO HYDROGEN ENERGY 9

Salient Characteristics of Hydrogen - Global Status and Importance of Hydrogen Energy – Global and National policies on Hydrogen - Hydrogen as Green Energy.

UNIT – II PROPERTIES OF HYDROGEN 9

Physical and Chemical Properties of Hydrogen - Hydrogen Colour Codes based on types of Hydrogen in Energy Industry. Hazards - Types - Codes, Regulations and Standards

UNIT – III HYDROGEN PRODUCTION METHODS 9

Steam Reformation - Partial Oxidation - Reformation using alternate energy sources - Coal gasification - Biomass Conversion - Electrolysis - Photo dissociation and Photo catalytic Methods.

UNIT – IV HYDROGEN STORAGE METHODS 9

Introduction to Hydrogen Storage Methods – Physical and Chemical Methods - compressed Hydrogen – Liquefied Hydrogen – Metal Hydrides - Adsorbents, chemical Storage - Other Novel Methods - comparison - Safety and management of Hydrogen.

UNIT – V APPLICATIONS OF HYDROGEN ENERGY 9

Use of Hydrogen in ICE, Fuel Cells, and Hydrogen Sensors - Hydrogen Refuelling Stations and Hydrogen Transportation - Future Directions.

TOTAL: 45 PERIODS

OUTCOMES:

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

CO1 Appreciate the need for Hydrogen energy towards SDG.

CO2 Study and understand the properties of hydrogen and its salient features in terms of risks and safety.

CO3 Introduce the conventional and non-conventional methods of production of Hydrogen.

CO4 Understand the methods of storing hydrogen in various ways.

CO5 Discuss the various Hydrogen Conversion Systems and their practical applications along with future scopes.

REFERENCES:

1. Gupta, R. B., “Hydrogen Fuel: Production, Transport and Storage”, Taylor and Francis, 2009.
2. James Larminie and Andrew Dicks, “Fuel cell systems Explained”, Wiley publications, 2003.
3. Michael Hirscher, “Handbook of Hydrogen Storage”, Wiley-VCH, 2010.
4. Robert Huggins, “Energy Storage: Fundamentals, Materials and Applications”, 2nd edition, Springer, 2015
5. Ru-shiliu, Leizhang, Xueliang sun, “Electrochemical technologies for energy storage

and conversion", Wiley publications, 2012.

6. Agata Godula Jopek, "Hydrogen Production by Electrolysis", Wiley-VCH, 2015.
7. Canan Acar, Ibrahim Dincer, "Comprehensive Energy Systems", Elsevier, 2018.
8. Godfrey Boyle, "Renewable Energy: Power for a Sustainable Future", Oxford University Press, 2012.
9. World Energy Outlook 2019, International Energy Agency, 2019.
10. India 2020 Energy Policy Review, International Energy Agency, 2020.

CO – PO MAPPING:

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1	2	3	-	-	3	1
2	2	3	-	-	3	1
3	2	3	-	-	3	1
4	2	3	-	-	3	1
5	2	3	-	-	3	1
Avg	**2**	**3**	**-**	**-**	**3**	**1**

EY3063 NANOMATERIALS FOR ENERGY SYSTEMS

	L	T	P	C
	3	0	0	3

OBJECTIVE:

To understand the properties, synthesis, characterization, significance of nanomaterials for Energy Systems and to impart the knowledge on applications of nanomaterials in the field of Solar Energy, Hydrogen energy and Carbon capture.

UNIT – I INTRODUCTION TO NANOMATERIALS 9

Nanotechnology - Classification of Nanomaterials - Nanoscale and bulk materials - Comparison.

UNIT – II PROPERTIES OF NANOMATERIALS 9

Mechanical Properties of Nanomaterials, Optical Properties of Nanomaterials - Electrical and Magnetic Properties of Nanomaterials – Physical - Chemical Properties.

UNIT – III SYNTHESIS AND CHARACTERIZATION OF NANOMATERIALS 9

Top Down and Bottom-Up Approaches - Synthetic Routes - Colloidal, Sol-gel, Electrodeposition - Aerosol Synthesis - Spray Pyrolysis - Electrospinning - Core/Shell Structures - Carbon-based Nanomaterials.
Characterization Methods - XRD, SEM, TEM, AFM, FTIR and XPS.

UNIT – IV NANOMATERIALS FOR SOLAR CELLS AND FUEL CELLS 9

Nano, Micro, Polycrystalline and Amorphous Si for Solar Cells - Organic Solar Cells Dye-sensitized Solar Cells - Organic-Inorganic Hybrid Solar Cells - Carbon Electrodes and Graphene based materials for Fuel Cells - Polymer Membranes.

UNIT – V NANOMATERIALS FOR HYDROGEN STORAGE AND CARBON CAPTURE 9

Hydrogen Energy and its Merits as Fuel - Hydrogen Storage Methods - Metal Hydrides - Physisorption of Hydrogen - Nanoscale Materials - Nanoparticles as 3D Support - Carbon Nanotubes and Other Novel Methods for Hydrogen Storage - GHG Emissions - CO_2 Capture and Sequestration Methods - Adsorption and Absorption Materials.

TOTAL: 45 PERIODS

OUTCOMES:

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

CO1 Appreciate the need for nanomaterials for energy systems.
CO2 Study and understand the properties of nanomaterials and their unique characteristics.
CO3 Introduce the synthetic methods and characterization of nanomaterials.
CO4 Understand the importance of nanomaterials for solar cells and fuel cells.
CO5 Discuss the scope of using nanomaterials for storing hydrogen and capturing carbon.

REFERENCES:

1. Vollath D, “Nanomaterials - An introduction to Synthesis, Properties and Applications”, Wiley-VCH, 2013.
2. Cao G, “Nanostructures and Nanomaterials - Synthesis, Properties and Applications”, Imperial College Press, 2006.
3. Michael Hirscher, “Handbook of Hydrogen Storage”, Wiley, 2010.
4. Robert Huggins, “Energy Storage: Fundamentals, Materials and Applications”, 2nd

edition, Springer, 2015
5. Robert A Varin, “Nanomaterials for Sold State Hydrogen Storage”, Springer, 2007.
6. Berendsmit, “Introduction to Carbon Capture and Sequestration”, Imperial College Press, 2014.
7. Yao N and Wang Z L, “Handbook of Microscopy for Nanotechnology”, Springer, 2005.
8. Harold P K and Leory E A, “X-Ray Diffraction Procedures”, Wiley Interscience, 1974.
9. Jenny Nelson, “The Physics of Solar Cells”, Imperial College Press, 2003.
10. Stephen F, “Solar Cell Device Physics”, Academic Press, 2010.

CO – PO MAPPING:

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1	2	2	-	-	1	1
2	3	1	-	2	-	2
3	3	1	-	2	2	3
4	3	3	-	1	3	3
5	3	3	-	2	3	3
Avg	**2.8**	**2**	-	**1.75**	**2.25**	**2.4**

EY3005 NUCLEAR ENGINEERING

L	T	P	C
3	0	0	3

COURSE OBJECTIVE:

The objective of this course is to provide in-depth knowledge to students on fundamentals of power generation using various types of Nuclear Power Plant. In addition, this course is intended to impart knowledge to students about different types of nuclear waste disposal techniques and radiation protection methods.

UNIT – I NUCLEAR REACTIONS 9

Mechanism of nuclear fission - nuclides - radioactivity – decay chains - neutron reactions - the fission process - reactors - types of fast breeding reactor - design and construction of nuclear reactors - heat transfer techniques in nuclear reactors - reactor shielding

UNIT – II REACTOR MATERIALS 9

Nuclear Fuel Cycles - characteristics of nuclear fuels - Uranium - production and purification of Uranium - conversion to UF4 and UF6 - other fuels like Zirconium, Thorium – Beryllium

UNIT – III REPROCESSING 9

Nuclear fuel cycles - spent fuel characteristics - role of solvent extraction in reprocessing - solvent extraction equipment

UNIT – IV SEPARATION OF REACTOR PRODUCTS 9

Processes to be considered - 'Fuel Element' dissolution - precipitation process – ion exchange – redox - purex - TTA - chelation -U235 - Hexane - TBP and thorax Processes - oxidative slagging and electro - refining - Isotopes - principles of Isotope separation

UNIT – V WASTE DISPOSAL AND RADIATION PROTECTION 9

Types of nuclear wastes - safety control and pollution control and abatement - international convention on safety aspects - radiation hazards prevention

TOTAL: 45 PERIODS

OUTCOMES:

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

CO1 Understand fundamentals of nuclear reactions
CO2 Have knowledge in characteristics of various nuclear fuels
CO3 Aware about reprocessing of spent fuel and waste disposal
CO4 Have knowledge about separation of reactor products
CO5 Aware about radiation protection methods

REFERENCES:

1. Cacuci, Dan Gabriel, “Nuclear Engineering Fundamentals”, Springer, 2010
2. Kenneth Shultis J., Richard E. Faw, “Fundamentals of Nuclear Science and Engineering”, CRC Press; 3rd Edition, 2016
3. Kenneth D. Kok, “Nuclear Engineering”, CRC Press, 2009
4. Lamarsh, J.R., “Introduction to Nuclear Reactor Theory”, Wesley, 2002
5. Tatjana Tevremovic, “Nuclear Principles in Engineering”, Springer, 2008

CO – PO MAPPING:

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1	2	3	-	3	3	3
2	3	3	-	3	3	2
3	2	3	-	1	3	2
4	2	3	-	1	3	2
5	2	3	-	3	3	2
Avg	**2.2**	**3**	-	**2.2**	**3**	**2.2**