ANNA UNIVERSITY, CHENNAI

UNIVERSITY DEPARTMENTS

REGULATIONS - 2023

CHOICE BASED CREDIT SYSTEM

M.E. THERMAL ENGINEERING (PART TIME)

THE VISION OF THE DEPARTMENT OF MECHANICAL ENGINEERING

To be recognized globally for its excellence in Engineering and Research in the field of Mechanical and allied disciplines.

THE MISSION OF THE DEPARTMENT OF MECHANICAL ENGINEERING

- To provide world class education through the conduct of pioneering and cutting–edge research that inculcate professional, technical, critical thinking and communication skills necessary for students and faculty to make impactful contribution to the need of sustainable society.
- To expand the frontiers of engineering and science and technological innovation while forecasting academic excellence and scholarly learning in a collegial environment.
- To attract highly motivated students with enthusiasm, aptitude, and interest in the field of Mechanical and allied Engineering.
- To excel in industrial consultancy and research leading to innovative technology development and transfer.
- To serve the society with Innovative and entrepreneurially competent graduates for the local, national, and international community in a sustainable way.

REGULATIONS – 2023: CHOICE BASED CREDIT SYSTEM

M.E. THERMAL ENGINEERING (PART TIME)

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs) :

PEO1: Acquire knowledge and employability skills in thermal energy sector with requisite skills facilitating quick progress in graduands career

PEO2: Conduct multi-disciplinary research resulting in development of tangible applications and provide solutions to social and technical challenges.

PEO3: To develop innovative technologies and find solutions to contemporary issues in Thermal Engineering field using fundamental principles in combination with modern engineering tools and methods.

PEO4: To provide students with an academic environment of professional excellence and leadership through interaction with practicing engineers and lifelong learning.

PROGRAMME OUTCOMES (POs):

PO 1: An ability to independently carry out research/investigation and development work to solve practical problems.

PO 2: An ability to write and present a substantial technical report/document.

PO 3: An ability to demonstrate a degree of mastery in the field of thermal engineering. The mastery should be at a level higher than the requirements in the appropriate bachelor programme.

PO 4: An ability to design solutions for complex problems that meet the specified needs with appropriate consideration for the public safety along with cultural, societal, and environmental considerations.

PO 5: An ability to utilize modern tools to create, select, and apply appropriate techniques, resources towards successful design and development of thermal systems

PO 6: An ability to optimize thermal energy systems with environmental consciousness for sustainable development.

PEO/PO Mapping:

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

PROGRAM ARTICULATION MATRIX OF ME THERMAL ENGINEERING [PART TIME]

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
		Research Methodology and IPR	3	3	2	-	-	-
	II	Instrumentation and Control for Thermal Systems	3	2	2		2	2
		Refrigeration Cycles and Systems	3	-	1	-	3	3
		Computational Fluid Dynamics for Energy Systems	1.25	-	-	2	1.6	2.5
		Thermal Simulation Laboratory	1.67	2	-	2	-	1.5
II	III	Combustion in IC Engines	3	2	2		3	2
		HVAC Systems	3		1		3	3
		Professional Elective I						
	IV	Professional Elective II						
		Professional Elective III						
		Professional Elective IV						
		Technical Seminar	3	3	3		2	
III	V	Professional Elective V						
		Project Work – I	3	3	3	3	3	3
	VI	Project Work – II	3	3	3	3	3	3
PEC		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
		Advanced Power Plant Engineering	3	2.2	2	-	3	2
		Design and Analysis of Turbo Machines	3	-	2	2	3	-
		Energy Forecasting, Modelling and Project Management	2.3	1.8	2.8	2.6	2.6	3.0
		Modeling and Analysis of Energy Systems	2.2	1.7	1.7	2.6	2.4	1.7
		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
		Nano materials for Energy systems	2.8	2	-	1.75	2.25	2.4
		Fuel and Combustion Technology	3	2	-	-	3	1.5
		Engine Emission and Control Technologies	3	2	2	-	3	2
		Electronic Engine Management Systems	3	2	2	2	3	1
		Design of Engine Components and Testing	2	3	2.6	2.2	2	2.2
		Thermal Management of Electronics and Batteries	1.25	-	1	1.6	-	1.4
		Machine Learning in IC Engines	3	1.4	2	-	3	1.5
		Advanced Combustion Concepts in Engines	3	2.4	-	-	3	1.5
		Design of Heat Exchangers	1.25	1	1.8	3	2.33	1.25
		Sorption Heating and Cooling Systems	2.6	1	2.4	3	2.2	2.6

Year	Sem	Courses	PO					
			1	2	3	4	5	6
		Low Temperature Refrigeration and Cryogenics	2.8	-	1	-	2.8	2.8
		Chilled water and Air Handling Systems	2.4	1.4	2.8	3	2	1
		Cold Chain Systems and Management	1.2	-	1.6	1.8	1.6	-
		Energy Audit for HVAC Systems	1	2.5	-	2	-	1.2

ANNA UNIVERSITY, CHENNAI

UNIVERSITY DEPARTMENTS

REGULATIONS - 2023

CHOICE BASED CREDIT SYSTEM

M.E. THERMAL ENGINEERING (PART TIME)

SEMESTER I

SL. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
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.	RM3151	Research Methodology and IPR	RMC	2	1	0	3	3
			TOTAL	**12**	**3**	**0**	**15**	**15**

SEMESTER II

SL. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.	RA3152	Instrumentation and Control for Thermal Systems	PCC	3	0	0	3	3
2.	TH3201	Refrigeration Cycles and Systems	PCC	4	0	0	4	4
3.	EY3251	Computational Fluid Dynamics for Energy Systems	PCC	3	1	0	4	4
PRACTICAL								
4.	RA3261	Thermal Simulation Laboratory	PCC	0	0	4	4	2
			TOTAL	**10**	**1**	**4**	**15**	**13**

SEMESTER III

SL. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.	IC3152	Combustion in IC Engines	PCC	3	0	0	3	3
2.	TH3301	HVAC Systems	PCC	4	0	0	4	4
3.		Professional Elective I	PEC	3	0	0	3	3
			TOTAL	**10**	**0**	**0**	**10**	**10**

SEMESTER IV

SL. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.		Professional Elective II	PEC	3	0	0	3	3
2.		Professional Elective III	PEC	3	0	0	3	3
3.		Professional Elective IV	PEC	3	0	0	3	3
PRACTICAL								
4.	TH3411	Technical Seminar	EEC	0	0	4	4	2
			TOTAL	**9**	**0**	**4**	**13**	**11**

SEMESTER V

SL. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.		Professional Elective V	PEC	3	0	0	3	3
PRACTICAL								
2.	TH3511	Project Work – I	EEC	0	0	12	12	6
			TOTAL	**3**	**0**	**12**	**15**	**9**

SEMESTER VI

SL. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
PRACTICAL								
1.	TH3611	Project Work – II	EEC	0	0	24	24	12
			TOTAL	**0**	**0**	**24**	**24**	**12**

Total credits for the programme = 15+13+10+11+9+12 = 70

FOUNDATION COURSES (FC)

Sl. No	COURSE CODE	Course Title	Periods per week			Credits	Semester
			Lecture	Tutorial	Practical		
1.	MA3155	Advanced Numerical Methods	4	0	0	4	1

PROFESSIONAL CORE COURSES (PCC)

SL. NO.	COURSE CODE	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.	TH3201	Refrigeration cycles and Systems	3	0	0	3	2
4.	RA3152	Instrumentation and Control for Thermal Systems	3	1	0	4	2
5.	RA3261	Thermal Simulation Laboratory	0	0	4	2	2
6.	IC3152	Combustion in IC Engines	3	0	0	3	3
7.	TH3301	HVAC Systems	4	0	0	4	4

PROFESSIONAL ELECTIVE COURSES

SL. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
1.	EY3053	Polygeneration Systems	PEC	3	0	0	3	3
2.	EY3054	Waste to Energy conversion Systems	PEC	3	0	0	3	3
3.	EY3055	Energy Conservation in Buildings	PEC	3	0	0	3	3
4.	EY3056	Industrial Refrigeration and Air Conditioning Systems	PEC	3	0	0	3	3
5.	EY3051	Advanced Power Plant Engineering	PEC	3	0	0	3	3
6.	EY3064	Design and Analysis of Turbo Machines	PEC	3	0	0	3	3
7.	EY3057	Energy Forecasting, Modelling and Project Management	PEC	3	0	0	3	3
8.	EY3058	Modelling and Analysis of Energy Systems	PEC	3	0	0	3	3
9.	EY3060	Statistical Design and Analysis of Experiments	PEC	3	0	0	3	3
10.	EY3061	Energy Storage Technologies	PEC	3	0	0	3	3

11.	EY3052	Fuel Cell Technology	PEC	3	0	0	3	3
12.	EY3062	Hydrogen Generation, Storage and Application	PEC	3	0	0	3	3
13.	EY3063	Nanomaterials for Energy systems	PEC	3	0	0	3	3
14.	TH3001	Fuel and Combustion Technology	PEC	3	0	0	3	3
15.	TH3002	Engine Emission and Control Technologies	PEC	3	0	0	3	3
16.	IC3251	Electronic Engine Management Systems	PEC	3	0	0	3	3
17.	IC3252	Design of Engine Components and Testing	PEC	3	0	0	3	3
18.	RA3053	Thermal Management of Electronics and Batteries	PEC	3	0	0	3	3
19.	IC3053	Machine Learning in IC Engines	PEC	3	0	0	3	3
20.	IC3051	Advanced Combustion Technologies	PEC	3	0	0	3	3
21.	EY3065	Design of Heat exchangers	PEC	3	0	0	3	3
22.	RA3054	Sorption Heating and Cooling Systems	PEC	3	0	0	3	3
23.	RA3055	Low Temperature Refrigeration and Cryogenics	PEC	3	0	0	3	3
24.	RA3051	Chilled water and Air Handling Systems	PEC	3	0	0	3	3
25.	RA3052	Cold Chain Systems and Management	PEC	3	0	0	3	3
26.	RA3056	Energy Audit for HVAC Systems	PEC	3	0	0	3	3

RESEARCH METHODOLOGY AND IPR COURSE (RMC)

SL. NO.	COURSE CODE	COURSE TITLE	CATEGORY			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	CATEGORY			Credits	Semester
			Lecture	Tutorial	Practical		
1	TH3411	Technical Seminar	0	0	4	2	4
2	TH3511	Project Work – I	0	0	12	6	5
3	TH3611	Project Work – II	0	0	24	12	6
					Total Credits	**20**	

Summary

S.No.	M.E. THERMAL ENGINEERING (PT)							
	Subject Area	Credits per Semester						Credits Total
		I	II	III	IV	V	VI	
1.	FC	4						4
2.	PCC	8	13	7				28
3.	PEC			3	9	3		15
4.	MC	3						3
5.	EEC				2	6	12	20
	Total Credit	**15**	**13**	**10**	**11**	**9**	**12**	**70**

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**

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.

RA3152	INSTRUMENTATION AND CONTROL FOR THERMAL SYSTEMS	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES:

- To impart students with the fundamental background as well as practical knowledge to precisely measure and quantify various parameters in thermal systems.

UNIT – I DATA ANALYSIS 9

Statistical analysis of data, Regression analysis, Uncertainty analysis, Data reduction, Design of Experiments – Experimental design factors and protocols, Introduction to Data Analytics and Machine Learning.

UNIT – II SENSORS AND CALIBRATION 9

Transducers – LVDT, Strain gauge, Capacitive, Piezoelectric, Photoelectric, Photoconductive, Photovoltaic, Ionization, Magnetometer Search Coil, Hall-Effect, Temperature Sensors – Thermocouple, RTD, Thermistor. Calibration of Temperature and pressure sensors.

UNIT – III MEASUREMENTS IN THERMAL SYSTEMS 9

Temperature, pressure and flow measurements. Thermal conductivity, Specific heat, viscosity, rheological analysis of Newtonian and non-Newtonian fluids, Humidity, Solar irradiation, Differential Scanning Calorimeter, Calorific values of Solid, liquid and gaseous fuels. Case Studies and Report preparation.

UNIT – IV CONTROL SYSTEMS AND COMPONENTS 9

Open and closed loop control, Transfer function, Interfaces & Protocols. Types of feedback and feedback control system characteristics – Control system parameters, Signal conditioning and processing. Data Acquisition System

UNIT – V CONTROLLERS 9

PID Controllers, Programmable Logic Controllers, Telemetry, Transmitters – Electronic, Fibre-optic & Pneumatic, Regulators – Flow, Level, Pressure and Temperature, Thermostats and Humidistats, Variable-speed drive, Control & optimisation of operations – Cooling Tower, Clean Room, Furnace, pump and turbine, waste water treatment, SCADA, DCS, Industrial Internet of Things.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

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

1. Interpret the of sensitivity, resolution, random and bias error, and precision and accuracy in evaluating data.
2. Illustrate operating principles, calibration, and use of sensors for different measurements.
3. Classify the various measurement techniques, perform experiments and prepare technical reports.
4. Demonstrate the knowledge and understanding of data acquisition.
5. Outline and distinguish the various controllers suitable for thermal systems.

REFERENCES:

1. Holman, J.P., Experimental methods for Engineers, Tata McGraw-Hill, 7th Ed.2011.
2. Ernest O. Doebelin, Measurement Systems: Application and Design, McGraw-Hill, 2004.
3. Les Kirkup, Experimental Methods for Science and Engineering Students, Cambridge University Press, 2019.
4. Alan S. Morris, Reza Langari, Measurement and Instrumentation: Theory and Application, Elsevier, 2015.
5. Norman A. Anderson, Instrumentation for Process Measurement and Control, CRC Press,2017.
6. Aniruddha Datta, Pankaj Goel, Practical Guide to Instrumentation, Automation and Robotics, Elsevier, 2023.
7. Liptak, Instrument Engineers' Handbook, CRC Press, 2018

Mapping of CO with PO

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1	-	1	2	1	-	-
2	2	-	3	2	-	-
3	1	2	1	1	-	-
4	1	-	3	1	-	2
5	1	-	1	1	2	2
Avg.	1.25	1.5	2	1.2	2	2

TH3201	REFRIGERATION CYCLES AND SYSTEMS	L	T	P	C
		4	0	0	4

COURSE OBJECTIVE

The main objective of the course is to impart knowledge on various Refrigeration cycles, system components and cooling load estimations.

UNIT - I THERMODYNAMIC ANALYSIS OF REFRIGERATION CYCLES 12

Reversed Carnot cycle, Ideal and Actual VCR cycle, Aircraft refrigeration cycle, Factors influencing performance, Multi pressure Cycles, Cascade Cycle

UNIT – II REFRIGERANTS AND ENVIRONMENTAL CONSIDERATIONS 12

Types of Refrigerants, Refrigerant Designation, Refrigerant selection, International protocols on Environmental impact of Refrigerants, Eco Friendly Refrigerants in different sectors, ODP, GWP, Safety standards, Refrigerant-oil relationship, Energy Efficiency of Refrigerants, Sustainable Refrigerants

UNIT – III REFRIGERATION SYSTEM COMPONENTS 12

Classification and performance aspects of Compressors, Condensers, Expansion devices, Evaporators. LSHX, Receivers, Driers, Accumulators, suction line risers, Control and safety devices, Refrigeration system accessories, Oil management and Lubrication.

Types of Electric drives, Starting Relays, Overload protecting Relays, Electric Circuits for domestic and commercial appliances.

UNIT – IV COOLING LOAD CALCULATIONS 12

Estimation of Cooling Load, Cold Storages, Cool Storages, System Balancing – Graphical Analysis, Capacity modulation and Cycling Controls

UNIT – V ALTERNATIVE REFRIGERATION TECHNOLOGIES 12

Introduction to super-critical CO2 refrigeration system, Vapour absorption systems, Steam-Jet, Thermoelectric Refrigeration, Vortex Refrigeration, Magnetic Refrigeration.

TOTAL: 60 PERIODS

COURSE OUTCOMES

On successful completion of the course the student will be able to

1. Demonstrate a comprehensive understanding of the fundamental principles of refrigeration
2. Comprehend Environmental Impact and Safety Regulations of Refrigerants.
3. Understand and Evaluate the various components of Refrigeration systems.
4. Analyse and Design the system load in-order to evolve a balanced system.
5. Understand advanced refrigeration technologies and analyze their potential application and benefits.

REFERENCES:

1.Arora, C.P., Refrigeration and Air conditioning, McGraw Hill, 3rd Ed., 2010.
2. Dossat R.J., Principles of refrigeration, John Wiley, S.I. Version, 2001.
3. Ibrahim Dincer, Refrigeration Systems and Applications, John Wiley & Sons, 2017.
4.Jordan and Priester, Refrigeration and Air conditioning 1985.
5. Langley, Billy C., 'Solid state electronic controls for HVACR' Prentice-Hall 1986.
6.Stoecker W.F., Refrigeration and Air conditioning, McGraw-Hill Book Company, 1989.
7.Rex Milter, Mark R.Miller., Air conditioning and Refrigeration, McGraw Hill, 2006.

Mapping of CO with PO

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

RA3261	THERMAL SIMULATION LABORATORY	L	T	P	C
		0	0	4	2

COURSE OBJECTIVE:

- To offer hands-on training on Modeling and simulation algorithms, and methods of energy-based systems.

LIST OF EXPERIMENTS

1. Solution to Laplace equation on a two-dimensional grid using program code.
2. Solution to linear wave equation on a two-dimensional grid using program code.
3. Simulation studies of fluid flow over a heated flat plate under laminar & turbulent flow conditions using CFD software
4. Heat transfer analysis from a heatsink for electronic cooling applications using CFD software.
5. Thermo-hydraulic performance of a tubular heat exchanger using CFD Software.
6. Simulation studies on Ventilation of space using CFD software.
7. Transient Simulation of HVAC systems.
8. Transient Simulation of solar water heating systems.
9. Energy Simulation of residential / commercial buildings.

TOTAL: 30 PERIODS

COURSE OUTCOMES:

Upon completion of this course, the students will be able to:
1. Develop models and perform simulation studies.
2. Analyse and interpret data of simulated results.
3. Prepare technical reports for simulation of thermal systems.

LAB REQUIREMENTS:

1) Software – CAD Modeling software, CFD Meshing Software, FVM based CFD Solvers, Post-Processing tools, programming & computing software, equation-solving program, building energy simulation software, transient energy simulation software.
2) Computer Hardware compatible with the requirements of the above software.

Mapping of CO with PO

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1	1	1	-	2	-	2
2	2	2	-	2	-	1
3	2	3	-	2	-	-
Avg.	1.67	2	-	2	-	1.5

IC3152 **COMBUSTION IN IC ENGINES**

L	T	P	C
3	0	0	3

COURSE OBJECTIVES

1. To familiarize with the principles of combustion in engines and modern concepts of combustion

UNIT I THERMODYNAMICS OF COMBUSTION 9

Properties of Mixtures, Combustion Stoichiometry - Methods of Quantifying Fuel and Air Content of Combustible Mixtures, Heating Values - Determination of HHV for Combustion Processes at Constant Pressure - Determination of HHV for Combustion Processes from a Constant-Volume Reactor - Representative HHV Values, Adiabatic Flame Temperature, Constant-Pressure Combustion Processes, Comparison of Adiabatic Flame Temperature Calculation Method

UNIT II COMBUSTION PRINCIPLES 9

Combustion – Combustion equations, chemical equilibrium, and Dissociation -Theories of Combustion - Flammability Limits - Reaction rates - Laminar and Turbulent Flame Propagation in Engines, Flame structure and speed - Chemical kinetics.

UNIT III COMBUSTION IN S.I. ENGINES 9

Stages of combustion, Cylinder pressure measurement and heat release analysis normal and abnormal combustion, knocking, Variables affecting Knock, Features and design consideration of combustion chambers, Types of combustion chambers., Cyclic variations, Lean burn combustion, Stratified charge combustion systems. Heat release correlations.

UNIT IV COMBUSTION IN C.I. ENGINES 9

Stages of combustion, and spray formation and characterization, air motion, swirl measurement, knock and engine variables, Features and design considerations of combustion chambers, delay period correlations, heat release correlations, Influence of the injection system on combustion, Direct and indirect injection systems.

UNIT V LOW TEMPERATURE COMBUSTION CONCEPTS 9

Homogeneous charge compression ignition (HCCI) engine – Premixed charge compression ignition (PCCI) engine, Gasoline Direct Injection Compression Ignition (GDCI) engine, Reactivity controlled compression ignition (RCCI) engine – An introduction.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

On successful completion of this course the student will be able to

CO1 Knowledge to apply laws of thermodynamics to combustion processes
CO2 Understanding and Analysing ability on theories of combustion, flame, and flame structure
CO3 Acquired knowledge on SI normal and abnormal combustion
CO4 Acquired knowledge on CI stages of combustion and various factors influencing CI combustion
CO5 Gained brief knowledge about various low temperature combustion schemes and its benefits.

REFERENCES:

1. McAllister, Sara; Chen, Jyh-Yuan; Fernandez-Pello, A. Carlos (2011). [Mechanical Engineering Series] Fundamentals of Combustion Processes, 10.1007/978-1-4419-7943-8,–doi:10.1007/978-1-4419-7943-8.
2. Ganesan, V, Internal Combustion Engines, Tata McGraw Hill Book Co., 2003.
3. John B. Heywood, Internal Combustion Engine Fundamentals, McGraw Hill Book, 1998.
4. Pundir B P, I.C. Engines Combustion and Emission, 2010, Narosa Publishing House.
5. Gupta H.N. Fundamentals of Internal Combustion Engines, Prentice Hall of India, Ltd, 2nd Edition, 2006.
6. Williard W Pulkrabek, Engineering Fundamentals of IC Engines, Prentice Hall of India, 2004.

CO – PO MAPPING:

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

TH3301 **HVAC SYSTEMS**

L	T	P	C
4	0	0	4

OBJECTIVE:

To provide students with a strong foundation in HVAC principles, design, selection, performance evaluation and applications.

UNIT – I FUNDAMENTALS OF HVAC SYSTEMS 12

Thermodynamics and heat transfer principles in HVAC, Psychrometrics and air conditioning processes, Indoor air quality (IAQ) and comfort parameters.

UNIT – II THERMAL COMFORT MODELS 12

Psychrometric analysis of Summer and Winter air conditioning, Selection of design conditions Thermal Comfort models, Comfort charts, Adaptive Thermal Comfort models, Indoor Air Quality, Clean room concepts.

UNIT – III COOLING LOAD CALCULATIONS 12

Heat transmission through building envelope, Solar radiation, Infiltration & ventilation loads, Cooling and heating load calculations. Passive Airconditioning, ECBC norms, Green Building principles Methods to reduce AC load. Sustainable cooling solutions.

UNIT – IV AIR DISTRIBUTION IN HVAC SYSTEMS 12

Flow through Ducts, Static and Dynamic Losses, Diffusers, Duct Design – Equal Friction Method and Static Regain Method, Duct Balancing. Fan Duct Interactions, Selection of Fans, - Fan Coil units.

UNIT – V HVAC SYSTEMS – CONSTRUCTION AND WORKING 12

Room Air Conditioners, Packaged Air conditioning systems, Centralized Air conditioning systems, Radiant cooling systems, DCV and VAV systems, UFAD systems, Hydronic systems, Air handling systems. MAC systems.

TOTAL: 60 PERIODS

OUTCOMES:

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

CO 1 Demonstrate a solid understanding of the fundamental principles of thermodynamics, heat transfer, and fluid mechanics as they apply to HVAC systems.

CO 2 Understand the importance of ventilation in maintaining indoor air quality, occupant health, and comfort.

CO 3 Develop the skills to perform load calculations, select appropriate HVAC equipment, and design heating and cooling systems for various building types and applications.

CO 4 Demonstrate the ability to size, design, and layout ductwork and piping systems for efficient air distribution and heat transfer. .

CO 5 Describe and Compare the different Air-conditioning systems to make best use of available models.

REFERENCES:

1. Arora C.P., Refrigeration and Air Conditioning, Tata McGraw Hill Pub. Company,2010.
2. ASHRAE, Fundamentals and equipment , 4 volumes-ASHRAE Inc. 2021.
3. Ali Vedavarz, Sunil Kumar, Mohammed Iqbal, Hussain Handbook of Heating, Ventilation and Air conditioning for Design Implementation, Industrial press Inc,2017.
4. Billy C. Langley., Fundamentals of Air Conditioning Systems, The Fairmont Press,

Carrier Air Conditioning Co., Handbook of Air Conditioning Systems design, McGraw Hill, 1985
5. Jones, Air Conditioning Engineering, Edward Amold pub. 2001.

CO – PO MAPPING

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

TH3411 **TECHNICAL SEMINAR**

L	T	P	C
0	0	4	2

OBJECTIVE:

The main learning objective of this course is to prepare the students for acquiring skills of oral presentation in seminars and conferences and technical writing abilities for journal publications.

GUIDELINES:

- The students will work for two hours per week guided by a group of staff members.
- They will be asked to talk on any topic of their choice related to Engineering design topics and to engage in dialogue with the audience.
- A brief copy of their talk also should be submitted.
- Similarly, the students will have to present a seminar of not less than fifteen minutes and not more than thirty minutes on the technical topic.
- They will also answer the queries on the topic.
- The students as audience also should interact.
- Evaluation will be based on the technical presentation and the report and also on the interaction during the seminar.

TOTAL: 180 PERIODS

OUTCOMES:

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

CO1 Comprehend concepts and methods for inductive and deductive reasoning of technical contents.

CO2 Develop report writing skills.

CO3 Develop oral presentation skills.

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	
Avg	3	3	3		2	

TH3511	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

TH3611 **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**

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**

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, 6th 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**

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**	**-**

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**

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 ANALYSE 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 - CO2 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**

TH3001 FUEL AND COMBUSTION TECHNOLOGY

L	T	P	C
3	0	0	3

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 9

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 9

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

UNIT – III LIQUID & GASEOUS FUELS 9

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 9

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 9

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: 45 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

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**

TH3002 ENGINE EMISSION AND CONTROL TECHNOLOGIES

L	T	P	C
3	0	0	3

OBJECTIVE:

To provide an insight about effect of engine out emissions on human health and environment, emission formation and techniques to measure and mitigate them.

UNIT – I INTRODUCTION 9

Atmospheric pollution from automotive, stationary engines and gas turbines, Global warming – Green-house effect, Effects of engine pollution on human health and environment.

UNIT – II POLLUTANT FORMATION 9

Formation of Oxides of Nitrogen, Carbon monoxide, Hydrocarbon, Aldehydes, Smoke and Particulate matter emissions. Effect of Engine design and operating variables on emission formation.

UNIT – III EMISSION MEASUREMENT TECHNIQUES 9

CO, CO_2 - Non dispersive infrared gas analyser, NO_x - Chemiluminescent analyser, HC - Flame ionization detector, Smoke – Opacity and filter paper measurements, Particulate Matter – Full flow and Partial flow dilution tunnel, Gas chromatography, Noise measurement.

UNIT – IV EMISSION CONTROL TECHNIQUES 9

Engine design modifications, Fuel modification, Evaporative emission control, EGR, Air injection, Water injection, Common rail direct injection, and Gasoline direct injection system, After treatment systems - Catalytic converters, Diesel oxidation catalyst, Particulate traps, De-NO_x catalysts, SCR systems.

UNIT – V DRIVING CYCLES AND EMISSION STANDARDS 9

Transient dynamometer, Test cells, Driving cycles for emission measurement, chassis dynamometer, CVS system, National and International emission standards, RDE

TOTAL: 45 PERIODS

OUTCOMES:

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

CO1 Understand about atmospheric pollution from engines and its impact on human health and environment.

CO2 Understand the formation of emissions in both SI and CI engines.

CO3 Understand the various measurement techniques used globally for the measurement of automotive and stationary engine out emissions.

CO4 Learn the various control methods/techniques used in IC engine to control the engine out emissions

CO5 Learn the transient and steady state driving cycles performed on automotive and stationary engines and emission standards that are followed in the national and international level.

REFERENCES:

1. Ganesan V., “Internal Combustion Engines”, 5th Edition, Tata McGraw Hill, 2012.
2. Pundir B. P., Engine Emissions” , 2nd Edition, Narosa publishing house, 2017.
3. John. B. Heywood, “Internal Combustion Engine fundamentals” McGraw – Hill, 1988.
4. Ernest, S., Starkman, Combustion Generated Air Pollutions, Plenum Press, 1980.
5. Crouse William, Automotive Emission Control, Gregg Division /McGraw-Hill,1980

CO – PO MAPPING:

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

IC3251	ELECTRONIC ENGINE MANAGEMENT SYSTEMS	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

1. To provide basic grounding on electronics used in engine management, and how engine is managed electronically using these electronic devices for reduced emissions and performance

UNIT I ELECTRICAL AND ELECTRONICS PRINCIPLES 7

Voltage, current and resistance – Electrical components in series and parallel – Electrical Energy and Power – Direct Current and Alternating Current – Inductance and Capacitance – Diodes and Bipolar Junction and Field Effect Transistors – Analog and Digital Integrated circuits, Comparator- Logic gates – Microcontroller – Basics of Analog to Digital and Digital to Analog Converters, Potentiometer – Wheatstone bridge.

UNIT II SENSORS AND ACTUATORS 10

Sensors - Camshaft Position, Crank Position, Throttle Position, Valve position, Air flow, Pressure, Temperature, Speed, Exhaust gas Oxygen, Knock, NH_3, RF, DP, and Oxides of nitrogen, Principle of operation, construction and characteristics. Actuators – Intake throttle valves Pneumatic, EGR Valve, Waste Gate, Brushless DC motor and stepper motor, calibration of Electronic sensors and actuators.

UNIT III IGNITION SYSTEMS 8

Ignition fundamentals, Solid state ignition systems, High energy ignition systems, Electronic spark timing and control. Combined ignition and fuel management systems. Dwell angle calculation, Ignition timing calculation, Engine mapping, Lookup tables and maps.

UNIT IV GASOLINE INJECTION SYSTEMS 10

Open loop and closed loop systems, Single-point, Multi-point, Direct injection systems and Air assisted systems – Principles and Features, Types of injection systems, Idle speed, lambda, knock and spark timing control, simple fuel injection calculation, Fuel injection volume control for different engine operation

UNIT V DIESEL INJECTION SYSTEMS 10

Heat release, control of fuel injection, Inline injection pump, Rotary Pump and Injector – Construction and principle of operation, Electronic control, Common rail, unit injector and Piezoelectric fuel injector- Principle – Construction and principle of operation.

TOTAL:45 PERIODS

COURSE OUTCOMES:

On successful completion of this course the student will be able to

CO1 Learn the application of electronics in engine management systems
CO2 Able to choose the types of sensors
CO3 Decide on the type of ignition systems to be employed for different applications
CO4 Able to design gasoline injection systems
CO5 Demonstrate the capabilities of diesel fuel injection systems

REFERENCES:

1. Eric Chowanietz, Automobile Electronics, SAE Publications 1995
2. Robert Bosch, Gasoline Engine Management, Third Edition, Bentley Publications, 2004.
3. Robert Bosch, Diesel Engine Management, Fourth Edition, Newness Publications, 2005.
4. Tom Denton, Automotive Electrical and Electronic Systems, 4th Edition, Taylor and Francis Group,2004.
5. William B. Ribbens, Understanding Automotive Electronics, Sxith Edition, Elsevier Inc, 2002

CO – PO MAPPING:

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

IC3252	DESIGN OF ENGINE COMPONENTS AND TESTING	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

1. To introduce the concepts for designing engine components and testing

UNIT I DESIGN OF CYLINDER, CYLINDER HEAD AND PISTON 9

Introduction - Stress, fatigue, material selection, Determination of required displacement, Determination of number of cylinders and arrangement of cylinders, Determination of bore diameter & stroke length, Design of cylinder – cylinder head – piston – piston rings

UNIT II DESIGN OF CONNECTING ROD AND CRANK SHAFT 9

Design of connecting rod, Design of overhang and center crank shaft – for maximum bending – for maximum torsion.

UNIT III DESIGN OF VALVE TRAIN AND SUBSYSTEMS 9

Design of valve train components, Design of cooling system, Design of lubrication system, Manifold tuning, Selection of bearings and gaskets.

UNIT IV ENGINE TESTING 9

During engine development: Performance Testing - Emission Testing (Steady state, Transient and Real driving emissions) - Durability testing (Individual components, Complete engine) - Emission and performance tuning. During engine production: Hot test - Cold test.

UNIT V MODELING AND ANALYSIS 9

Modelling and analysis of designed components using computer aided design and analysis software, Generation of production drawings.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

On successful completion of this course the student will be able to

CO1 Design cylinder, cylinder head and piston.
CO2 Design connecting rod and crank shaft.
CO3 Design of valve train components and sub systems.
CO4 Demonstrate understanding about engine testing.
CO5 Model and analyze engine components.

REFERENCES:

1. Kevin Hoag, Brian Dondlinger, "Vehicular Engine Design", 2nd Edition, 2015, Springer Vienna.
2. Editors: Richard van Basshuysen and Fred Schaefer, "Internal Combustion Engine Handbook: Basics, Components, Systems and Perpectives", 2nd Edition, 2016, SAE International, USA.
3. R. S. Khurmi, J. K. Gupta, "A Textbook of Machine Design", 25th Edition, 2020, S. Chand.
4. A. Kolchin and V. Demidov, "Internal Combustion Engine Design", 1984, MIR Publishers, Moscow.
5. Editors: Bernard Challen and Rodica Baranescu, "Diesel Engine Reference Book", Second Edition, 1999, Butterworth-Heinemann, UK.

CO – PO MAPPING:

COs	PO					
	1	2	3	4	5	6
1	2	3	3	3	2	1
2	2	3	3	1	2	3
3	2	3	2	1	2	3
4	2	2	2	3	2	1
5	2	3	3	3	2	3
Avg.	2	3	2	2	2	2

RA3053 THERMAL MANAGEMENT OF ELECTRONICS AND BATTERIES

L	T	P	C
3	0	0	3

COURSE OBJECTIVES:

- To impart the knowledge on thermal management of electronic devices and batteries.
- To provide students with an appreciation for the application of heat transfer to problems in industries related to thermal management of electronics and batteries.

UNIT – I FUNDAMENTALS 9

Heat transfer modes, electronics packaging, Properties of materials used in electronics and equipment, contact and spreading resistances, heat sink design, Thermal Interface Materials & Heat Spreaders, Jedec Standards.

UNIT – II COOLING TECHNOLOGIES 9

Microchannels, Fluid selection, Jet impingement, Immersion cooling, Heat pipes, Vapour chambers, Thermoelectric coolers, MEMS / NEMS based cooling system. Current trends in cooling.

UNIT – III APPLICATIONS 9

Automobiles, Trains, Ships, Avionics, Data Centres, Laptop / Computers / Mobile phone, Internet of Things, Television, RADAR, Satellite Electronics, LED – Lights and Display units, LASER.

UNIT – IV BATTERIES 9

Types and comparison, Thermodynamics of Batteries – Energy Balance, Electrochemical Modelling – Surface, concentration, ohmic over potential and overall cell potential, Duty cycle, Performance of a battery cell, Thermal Behaviour of Batteries - Aging, Thermal runaway, heat generation rate, thermal behaviour model and impact.

UNIT – V BATTERY THERMAL MANAGEMENT SYSTEM 9

Mechanical and Thermal design of battery pack, Thermal management system – Air based, Liquid based and Phase Change Material based systems, Recent developments.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

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

1. Understand the heat transfer mechanisms, need for thermal management and sources of heat generation in electronics.
2. Compare and analyse the performance of various cooling technologies.
3. Select the appropriate cooling system for specific applications.
4. Categorise the major components of batteries and elucidate the battery characteristics.
5. Identify the challenges and requirements for thermal management of batteries.

REFERENCES:

1. Younes Shabany, Heat Transfer: Thermal Management of Electronics, CRC Press Inc, 2010.
2. L.T. Yeh, Thermal Management of Microelectronic Equipment, ASME, 2016.
3. Arman Vassighi, Manoj Sachdev, Thermal and power management of integrated circuits, Springer, 2006.
4. Marc A Rosen, Aida Farsi, Battery Technology: From Fundamentals to Thermal Behaviour and Management, Elsevier, 2023.
5. Shriram Santhanagopalan, Kandler Smith, Gi-Heon Kim, Jeremy Neubauer, Ahmad A. Pesaran, Matthew Keyers, Design and Analysis of Large Lithium-Ion Battery Systems, Artech House

Publishers, 2014.
6. Jerry E. Sergent, Al Krum, Thermal Management Handbook: For Electronic Assemblies, McGraw-Hill, 1998.
7. Shichun Yang, Xinhua Liu, Shen Li, Cheng Zhang, Advanced Battery Management System for Electric Vehicles, Springer, 2022.

Mapping of CO with PO

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1	1	-	1	2	-	1
2	2	-	1	2	-	1
3	1	-	1	2	-	1
4	-	-	1	1	-	2
5	1	-	1	1	-	2
Avg.	1.25	-	1	1.6	-	1.4

IC3053 MACHINE LEARNING IN IC ENGINES

L	T	P	C
3	0	0	3

COURSE OBJECTIVES

1. The objective of the course is to impart knowledge on the various machine learning aspects of IC engines

UNIT I INTRODUCTION AND MATHEMATICAL FOUNDATIONS 9

Machine Learning Need –History – Definitions – Applications - Advantages, Disadvantages & Challenges of Machine learning -Types of Machine Learning Problems – Mathematical Foundations - Linear Algebra & Analytical Geometry -Probability and Statistics- Bayesian Conditional Probability.

UNIT II SUPERVISED LEARNING 9

Introduction-Discriminative and Generative Models -Linear Regression - Least Squares - Under-fitting / Overfitting -Cross-Validation – Lasso Regression- Classification - Logistic Regression- Gradient Linear Models -Support Vector Machines –Kernel Methods -Instance based Methods - K-Nearest Neighbours - Tree based Methods –Decision Trees –ID3 – CART - Ensemble Methods –Random Forest.

UNIT III UNSUPERVISED LEARNING AND REINFORCEMENT LEARNING 9

Introduction - Clustering Algorithms -K – Means – Hierarchical Clustering - Cluster Validity - Dimensionality Reduction –Principal Component Analysis – Recommendation Systems - EM algorithm. Reinforcement Learning – Elements -Model based Learning – Temporal Difference Learning

UNIT IV PROBABILISITIC METHODS FOR LEARNING 9

Introduction -Naïve Bayes Algorithm -Maximum Likelihood -Maximum Apriori -Bayesian Belief Networks -Probabilistic Modeling of Problems -Inference in Bayesian Belief Networks – Probability Density Estimation - Sequence Models – Markov Models – Hidden Markov Models

UNIT V MODELING, DIAGNOSTICS AND OPTIMIZATION OF IC ENGINE 9

Conventional modeling approaches for ICE, Limitations of conventional ICE modeling, ICE modeling challenges, ML to address ICE optimization and calibration challenges, ML to address ICE control challenges, Combining ML-based control with conventional ICE calibration methods, ML For combustion stability control, ML to address ICE diagnostics challenges, Systematic decision tree for use of ML in ICEs, Optimum data required for ML-based ICE applications, ML for ICE component fault diagnostics

TOTAL: 45 PERIODS

COURSE OUTCOMES:

On successful completion of this course the student will be able to

CO1 Understand and outline problems for each type of machine learning

CO2 Implement Discriminative and Generative algorithms for an application and analyze the results.

CO3 Understand the Clustering Algorithms, EM Algorithm and Reinforcement Learning

CO4 Use a tool to implement different algorithms for different types of applications

CO5 Understand the modeling, diagnostic and optimization of IC engine using Machine learning Techniques

REFERENCES:

1. Stephen Marsland, “Machine Learning: An Algorithmic Perspective”, Chapman & Hall/CRC, 2nd Edition, 2014.
2. Kevin Murphy, “Machine Learning: A Probabilistic Perspective”, MIT Press, 2012
3. Tom M Mitchell, “Machine Learning”, McGraw Hill Education, 2013.
4. Hal Daumé III, “A Course in Machine Learning”, 2017 (freely Downloadable online)

CO – PO MAPPING:

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

IC3051 ADVANCED COMBUSTION TECHNOLOGIES

L	T	P	C
3	0	0	3

COURSE OBJECTIVES

1. To provide fundamental knowledge about low temperature combustion concepts
2. To impart in-depth knowledge about various advanced LTC methods
3. To impart knowledge on fuel requirements for LTC combustion and its effect

UNIT I FUNDAMENTALS OF LOW TEMPERATURE COMBUSTION 9

Introduction, low temperature combustion (LTC) Fundamentals – Background of LTC, Principle, Benefits, Challenges, Need for control.

UNIT II GASOLINE AND DIESEL LOW TEMPERATURE COMBUSTION 9

Conventional Gasoline and Diesel Combustion, Effects of EGR, Techniques to HCCI operation in gasoline engines, Overview of diesel HCCI engines, Techniques–Early Injection, Multiple injections, Narrow angle direct injection (NADI™) concept, Modulated kinetics (MK)combustion – First and Second generation of MK combustion, RCCI combustion, Gasoline Direct Injection Compression Ignition (GDCI) combustion.

UNIT III LOW TEMPERATURE COMBUSTION CONTROL 9

Control Methods, Combustion timing sensors, HCCI/SI switching, Transition between operating modes (HCCI-SI-HCCI), Fuel effects in HCCI - gasoline, diesel, auto-ignition requirement, combustion phasing, Influence of equivalence ratio, auto-ignition timing, combustion duration, auto-ignition temperature and auto-ignition pressure, Combustion limits, IMEP and indicated efficiency, other approaches to characterizing fuel performance in HCCI engines.

UNIT IV FUEL REQUIREMENTS FOR ADVANCED COMBUSTION 9

Introduction, Background, Diesel fuel HCCI, HCCI fuel ignition quality, Gasoline HCCI, HCCI fuel specification, Fundamental fuel factors

UNIT V LTC COMBUSTION WITH ALTERNATIVE FUELS 9

Natural gas HCCI engines, CNG HCCI engines, methane/n- butane/air mixtures. DME HCCI engine - chemical reaction model, Combustion completeness, Combustion control system, Methodof combining DME and other fuels, Unmixed-ness of DME/air mixture

TOTAL: 45 PERIODS

COURSE OUTCOMES:

On successful completion of this course the student will be able to

CO1 Understand the fundamentals of HCCI combustion, benefits and challenges
CO2 Learn the methods followed to achieve HCCI in Gasoline and Diesel engines
CO3 Learn the HCCI combustion control methods and its significance
CO4 Understand the fuel requirements for HCCI operation and its role on complete load range operation

CO5 Learn the HCCI operation with alternative fuels and its comparison over conventional fuels

REFERENCES:

1. Hua Zhao “HCCI and CAI Engines for automotive industry” Wood Head Publishing in Mechanical Engineering, 2007.
2. Pundir B.P., Engine Combustion and Emission, 2011, Narosa Publishing House.
3. Ganesan V., “Internal Combustion Engines”, 5th Edition, Tata McGraw Hill, 2012.
4. Pundir B. P., Engine Emissions” , 2nd Edition, Narosa publishing house, 2017.
5. John. B. Heywood, “Internal Combustion Engine fundamentals” McGraw – Hill, 1988.
6. HCCI Diesel Engines - NPTEL - https://nptel.ac.in/courses/112104033/34
7. HCCI and CAI Engines – NPTEL - https://nptel.ac.in/courses/112104033/33

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

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**

RA3054 SORPTION HEATING AND COOLING SYSTEMS

	L	T	P	C
	3	0	0	3

COURSE OBJECTIVES:

1. To teach fundamentals of sorption cooling systems and analysis and design of LiBr and Ammonia systems.
2. To teach pumpless system and solid sorption systems and their design of components.
3. To teach various applications of sorption systems for heating, cooling and power generation in buildings, industries etc.
4. To teach polygeneration systems
5. To teach the merits of the system for climate change mitigation

UNIT I INTRODUCTION 9

Carnot cycle : Refrigerator, Heat Pump, Heat Transformer - Working Fluids, Properties, Mixing of Fluids and the Heat of Mixing - Specific Heat of Mixtures – Thermodynamic processes - Desorption, Absorption, Condensation and Evaporation, Compression, Pumping, Throttling and Ammonia Purification

UNIT II LIQUID SORPTION SYSTEMS 9

Water–LiBr Systems; Single Effect, Double Effect Systems, Types–Analysis of Advanced Cycles for Refrigeration Systems–Heat Pumps and Heat Transformers, Membrane based Systems - Crystallization and other issues, Ammonia–Water Systems–Single Effect, Two stage and GAX Systems.

UNIT III PUMPLESS AND SOLID SORPTION SYSTEM 9

Diffusion Absorption Systems–Bubble Pump Systems–Solid Sorption Systems– Working Fluids–Single and Multi effect Systems–Metal Hydride Heating and Cooling Systems–Applications and Issues

UNIT IV COMPONENT DESIGN 9

Design of Generator – Absorber – Condenser – Evaporator – Solution Heat Exchanger – Reactors – Rectifiers – Overall System Balance.

UNIT V APPLICATIONS OF SOPRTION SYSTEMS 9

Combined power and cooling, Solar Cooling, Low and medium grade Industrial waste heat Utilization, Gas turbine inlet cooling, Polygeneration systems, Economics of Sorption Systems–Sorption refrigeration Systems for Climate Change Mitigation.

TOTAL : 45 PERIODS

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

1. Understand the fundamentals of sorption heating and cooling systems, processess and the working fluids requirement and their properties
2. Analyze the energy input requirements for both LiBr and Ammonia systems for various applications
3. Understand the principle of working in respects of pumpless refrigerators and solid sorption heating and cooling systems.
4. Design various components used both in liquid and solid sorption heating and cooling systems.

5. Appreciate the use of the systems for various building energy requirements such as heating, cooling and power and its ability for climate change mitigation.

REFERENCES

1. Alefeld G. and Radermacher R., Heat Conversion Systems, CRC Press, London,1994.
2. ASHRAE Hand Book–HVAC Systems & Equipment 2023, ASHRAE Inc. Atlanta.
3. Herold K. E., Radermacher R. and Klein S. A., Absorption Chillers and Heat Pumps, CRC Press, London, 2016.
4. Ibrahim Dincer, Tahir Abdul Hussain Ratlamwala., Integrated Absorption Refrigeration Systems: Comparative Energy and Exergy Analyses, Springer, 2016
5. Ibrahim Dincer and Yusulf bicer, Integrated Energy Systems for multigeneration, Elesvier Ltd, 2020
6. Franceso Calise, Maasimo Daccadia, Laura Vanoli and Maria Vicidomini, Polygeneration systems – Deign, Process and echnlogies, Academic Press, 2022
7. Majid Amidpour, Mohammad Hasan Khoshgoftar Manesh, Cogeneration and Polygeneration Systems, Elesevier Science, 2020

MAPPING OF CO'S WITH PO'S

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1	3	1	1	3	1	3
2	2	1	2	3	1	2
3	2	1	3	3	3	3
4	3	1	3	3	3	2
5	3	1	3	3	3	3
AVg.	2.6	1	2.4	3	2.2	2.6

RA3055 LOW TEMPERATURE REFRIGERATION AND CRYOGENICS

L	T	P	C
3	0	0	3

COURSE OBJECTIVE

To impart knowledge on Low Temperature Refrigeration as well as Cryogenics so that the students gain confidence in working independently with high end systems related to liquefaction of gases, Material behaviour at Cryogenic applications

UNIT I LOW TEMPERATURE REFRIGERATION 9

Temperature limits for Low Temperature Refrigeration and Cryogenics, Material characteristics, Applications of Low Temperature in Industries, Space, Medicine, Gas Industry, High Energy Physics, Super-conductivity, Levitation principle

UNIT II LIQUEFACTION OF GASES 9

Carnot Liquefaction Cycle, F.O.M. and Yield of Liquefaction Cycles. Inversion Curve- Joule Thomson, Effect. Linde Hampson Cycle, Precooled Linde Hampson Cycle, Claude Cycle Dual Pressure Cycle, Ortho-Para hydrogen conversion, Critical Components in Liquefaction Systems.

UNIT III PURIFICATION OF GASES 9

Principle of Rectification, Rectification ColumnAnalysis-McCabe Thiele Method, Adsorption Systems for purification.

UNIT IV CRYO COOLERS 9

J.T Cryo-coolers, Stirling Cycle Refrigerators, G.M.Cryo-coolers, Pulse Tube Refrigerators Regenerators used in Cryogenic Refrigerators, Magnetic Refrigerators.

UNIT V STORAGE AND TRANSPORT 9

Cryogenic Dewar Design, Cryogenic Transfer Lines. Insulations in Cryogenic Systems, Operating principle of different Types of Vacuum Pumps, Instruments to measure Flow, Level and Temperature operating principles

TOTAL: 45 PERIODS

COURSE OUTCOMES

On successful completion of the course the student will be able to:

1 Recognize and explain the material characteristics and Applications at Low temperature.

2. Analyse and evaluate the systems used for Liquefaction of Gases.

3. Understand and Evaluate the systems for purification of Gases.

4. Explain and Differentiate the different Cryo-coolers.

5. Discuss and Compare the different systems /components in handling the Cryogens.

REFERENCES:

1. Klaus D. Timmerhaus and Thomas M. Flynn, Cryogenic Process Engineering, Plenum Press NewYork, 1989.
2. Mukhopadhay Mamata, Fundamentals of cryogenic engineering, PHI learning, 2010.
3. Pipkov, "Fundamentals of Vacuum Engineering", Meer Publication.
4. Randall F. Barron, "Cryogenics Systems", Second Edition Oxford University Press New York, Clarendon Press, Oxford, 1985.
5. Thomas Flynn, Cryogenic Engineering, Revised and Expanded, CRC Press, 2004.

Mapping of CO with PO

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

RA3051 CHILLED WATER AND AIR HANDLING SYSTEMS

L	T	P	C
3	0	0	3

OBJECTIVE:

To understand the need, design, selection and analysis of various types of chillers and Air Handling units

UNIT – I WATER CHILLERS : FUNDAMENTALS, APPLICATION & OPERATION 9

Chilled Water for HVAC Applications - Determining the Chilled Water Supply Temperature Establishing the Temperature Range - Chiller Configurations -The Single-Chiller System, Multichiller Systems, One-Pump Parallel Configuration, Multiple-Pump Parallel Configuration, Primary Secondary Parallel Configuration, Variable Primary Flow Parallel Configuration , System Peak Cooling Load and Load Profile, Selecting Water Chillers , Basic Chiller Requirements, Part Load Efficiency. Load versus Capacity, Atmospheric Impacts, Mixed Energy Source Chiller Systems

UNIT – II CHILLER DESIGN AND APPLICATION 9

Chilled Water System Elements, Chiller Placement and Installation, Chilled Water Piping-Pump Selection and Piping- Chilled Water System Control and Performance - Cooling Thermal Energy Storage - Special Chiller Considerations

UNIT – III AIR-HANDLING UNITS 9

Psychrometric, Classifications of Air-Handling Units, Main components, Selection of Air-Handling units, economizer cycle, single zone system, multi zone system-Design Consideration, ductdesign static Regain-equal friction-T method.

UNIT – IV CONSTANT AND VARIABLE VOLUME SYSTEMS 9

Terminals reheat system, Double-Duct systems, Sub zone heating, Draw-through cooling, Triple- Duct system, Fan Coil Unit, Induction system. Various System Configurations - Hydronic heat pump, Heat recovery and Economizer, Indirect evaporative cooling, Energy conservation and system retrofit.

UNIT – V VENTILATION AND AIR CONTROLS 9

Ventilation, Measurements control and exhaust, Air cleaning devices, Rating and Assessments, Test method for air filters, and replacement-Air system, evaluation and control of the thermal Environment, Indoor Air Quality and Outside Air Requirements, Demand control ventilations, Thermostats, Damper and damper motor, Automatic Valves, Direct digital control, Application of fuzzy logic & neural network-Demand control ventilation

TOTAL: 45 PERIODS

OUTCOMES:

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

CO1 Know the various Chillers and its operations

CO2 Design the Chillers, on the Industrial requirements

CO3 Know the basic terms in psychrometric analysis, briefly about Air-Handling Units and duct design methods

CO4 Understand the constant and variable volume systems used in heating and cooling applications

CO5 Understand the ventilation in work environment and the digital controlling methods for the ventilation

REFERENCES:

1. Herbert W. Stanford III, HVAC Water Chillers and Cooling Towers Fundamentals, Application, and Operation , Second Edition , CRC PressTaylor & Francis Group Boca Raton London New York , 2011
2. Tseng-Yao Sun Air Handling Systems Design, McGraw-Hill Professional; 1st edition, 1994
3. Allan T. Kirkpatrick & James S. Elleson, cold air distributionsystem design guide, ASHEAC - 1996 USA.
4. John I. Levenhagen, Donald H. Spethmann, HVAC controls and systems, McGraw – Hill International Edition. NY – 1992.
5. Shan K.Wang, Handbook of Air-conditioning and Refrigeration, McGraw -Hill, 2001
6. SMACNA, HVAC System Duct Design, SMACNA Virginia - 1990.

CO – PO MAPPING:

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1	2	3	3	3	1	1
2	2	1	2	3	3	1
3	3	1	3	3	2	1
4	3	1	3	3	2	1
5	2	1	3	3	2	1
Avg.	2.4	1.4	2.8	3	2	1

RA3052 **COLD CHAIN SYSTEMS AND MANAGEMENT**

L	T	P	C
3	0	0	3

COURSE OBJECTIVES:

- To teach the fundamentals, concepts and types, facilities of various cold chains and its application for various sectors including socio-economic and environmental impacts.

UNIT – I FUNDAMENTALS 9

History of Cold storage, Traditional Methods, Modern Storage Methods, Controlled Atmosphere Storage, Modified Atmosphere Packing, Socio-economic and environmental impacts.

UNIT – II COLD CHAIN & REFRIGERATION 9

Cold chain – Components, Refrigerators, Logistics Management. Electrical Cold chain Equipment – Walk-in-Freezers, Walk-in-Coolers, Deep Freezers, Growth of Cold Storage industries

UNIT – III COLD CHAIN APPLICATIONS 9

Food cold chains – Handling, Storage & Transportation of Citrus, Mango, Pear, Banana, sub-tropical fruits, Fish and Meat. Medicinal and Vaccine cold chains.

UNIT – IV MANAGEMENT OF COLD CHAIN 9

Product Characteristics – Temperature & Humidity, Time, Chilling and Freezing Injury, Respiratory Metabolism. Monitoring Tools – Temperature Sensors, IoT, DAC, SCADA. Temperature Management – Multi-commodity management, Optimal Target Temperature Methods. Quality Assessment Methodologies.

UNIT – V WAREHOUSE 9

Types, Construction, Location, Functions, Site Selection, Storage Capacity, Basic Warehouse Equipment, Renewable energy based warehouses, Cost analysis.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

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

CO1 Classify the various types of cold chains and its applications.

CO2 Select the appropriate cold chain refrigeration system for various applications.

CO3 Elucidate the thrust applications of cold chain in Food and Healthcare sectors.

CO4 Infer the different control strategies in cold chain.

CO5 Design and analyse the warehouse for cold storage applications.

REFERENCES:

1. Myo Min Aung, Yoon Seok Chang, Cold Chain Management, Springer, 2022.
2. Ajay Kumar Gupta, The Complete Book on Cold Storage, Cold Chain & Warehouse, NIIR project consultancy services, 2022.
3. Chandra Gopala Rao, Engineering for Storage of Fruits and Vegetables: Cold Storage, Controlled Atmosphere Storage, Modified Atmosphere Storage, Elsevier, 2015.
4. Majeed Mohammed, Vijay Yadav Tokala, Cold Chain Management for the Fresh Produce Industry in the Developing World, CRC Press, 2021.
5. Luis Ruiz-Garcia, Development of Monitoring Systems for Cold Chain Logistics: Improving Food Safety through Emergent Sensing Technologies in the Cold Supply Chain, Lambert Acad. Publ., 2010.

CO – PO MAPPING

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1	1	-	2	2	2	-
2	1	-	1	2	2	-
3	1	-	1	2	1	-
4	1	-	1	1	1	-
5	2	-	3	2	2	-
Avg.	1.2	-	1.6	1.8	1.6	-

RA3056 ENERGY AUDIT FOR HVAC SYSTEMS

L	T	P	C
3	0	0	3

COURSE OBJECTIVES:

- To emphasise the essentiality and impart knowledge on energy audit in HVAC systems.

UNIT – I INTRODUCTION 9

Types of energy audit – Utility cost, Standard and Detailed Energy Audit, General Procedure. Energy Utility rates, Conventional & Renewable energy sources. Energy use Graphs

UNIT – II ELECTRICAL ENERGY AUDIT 9

Overview of Electrical equipment, Electrical Distribution system, Power Factor, Power quality, Various devices for electrical energy audit in Motors, Lighting systems – Fluorescent Lamps, Compact Fluorescent Lamps, Compact Halogen Lamps, LED, Lighting Controls, Appliances.

UNIT – III HVAC ENERGY AUDIT 9

Audit procedure – Commercial Buildings, Average annual energy performance, Electrical Loads, Electricity usage pattern, Thermal load calculation with respect to season for heating and cooling. Residential Buildings – Energy Consumption history, Energy evaluation – Outside wall, ceiling and roof evaluation, windows and doors. General forms and report preparation based on case studies.

UNIT – IV ENERGY AUDIT INSTRUMENTS 9

Electrical Measuring Instruments - Capacity, Power, Power Factor, Frequency, Reactive Power. Digital Multimeter, Power analyser. Thermometer – Contact, Non-contact. Hygrometer, Flow – Pitot, Ultrasonic, Coriolis. Speed – Tachometer, RADAR. Gas Leak Detectors, Lux Meters, Distance Meter, IAQ meter, Flue gas – Combustion analyser, Fyrite, Fuel Efficiency Monitor.

UNIT – V CASE STUDIES 9

Case Studies in Apartments, Schools, Colleges, Grocery Store, Hotel, IT park, Data Centres. Estimation and Forecasting of Carbon footprint. Building Energy management through Machine learning techniques.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

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

1. Explain the standard procedure for performing energy audit.
2. Relate the energy consumption of various electrical equipment and consumption patterns.
3. Estimate the energy consumption of electrical & HVAC appliances.
4. Make use of the various instruments used for energy audit.
5. Analyse the energy consumption in various sectors of buildings.

REFERENCES:

1. Moncef Krarti, Energy Audit of Building Systems, CRC Press, 2020.
2. Herbert C. Wendes, HVAC Procedures & Forms Manual, River Publishers, 2020.
3. Steve Doty, Commercial Energy Auditing Reference Handbook, Fairmont Press, 2011.
4. Tarik Al-Shemmeri, Energy Audits: A Workbook for Energy Management in Buildings, Wiley, 2011.
5. Chandan Kumar Shiva, Mohan Rao Ungarala, Shriram S. Rangarajan, Vedik Basetti, Artificial Intelligence and Machine Learning in Smart City Planning, Elsevier, 2003.

Mapping of CO with PO

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1	1	2	-	2	-	1
2	1	2	-	2	-	1
3	1	3	-	3	-	1
4	1	-	-	2	-	1
5	1	3	-	1	-	2
Avg.	1	2.5	-	2	-	1.2