ANNA UNIVERSITY, CHENNAI

UNIVERSITY DEPARTMENTS

M.E. (SOLAR ENERGY)

REGULATIONS - 2019

CHOICE BASED CREDIT SYSTEM

THE VISION OF THE DEPARTMENT OF MECHANICAL ENGINEERING

We, at the Department of Mechanical Engineering, Anna University shall strive hard to impart knowledge and state-of-the-art training to our students and expose them to broad areas of Mechanical Engineering, namely Design, Manufacturing, Energy, Thermal Sciences and currently related interdisciplinary areas, so that they can later practice their profession at home or abroad keeping in mind the needs and concern of the society they represent, safeguarding values, ethics and be instrumental in bringing about an overall technological development.

THE MISSION OF THE DEPARTMENT OF MECHANICAL ENGINEERING

1. To deliver knowledge in Mechanical Engineering and Materials Science and Engineering with high educational standards so that the outgoing students are employable and globally competitive.
2. To produce graduate and post graduate engineers with core competency as well as relevant software skills and social responsibility.
3. To be dynamic in imparting knowledge to students depending upon the changing national and International needs

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PROGRAMME EDUCATIONAL OBJECTIVES (PEOs) :

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

I. Acquire knowledge and accomplish a decent employment in solar energy sector and advance quickly to significant positions of leadership in their Profession.
II. Moving towards advanced research for mitigating the shortcomings in solar energy systems.
III. Ascending as a consultant for providing solutions towards increasing energy demand by moving towards decentralized solar energy systems.
IV. Become a successful entrepreneur and be a part of a supply chain or manufacture or market solar energy products for sustainable development.
V. Lead an ethical life by engaging in lifelong learning experiences for developing environmentally sustainable and economically affordable solar energy products for societal upliftment.

PROGRAMME OUTCOMES (POs):

After studying Energy Engineering, our students will exhibit ability to:

PO #	Graduate Attribute	Programme Outcome
1	Engineering knowledge	Apply knowledge of mathematics, basic science and engineering science.
2	Problem analysis	Identify, formulate and solve engineering problems.
3	Design/development of solutions	Design a system or process to improve its performance, satisfying its constraints.
4	Conduct investigations of complex problems	Conduct experiments & collect, analyze and interpret the data.
5	Modern tool usage	Apply various tools and techniques to improve the efficiency of the system.
6	The Engineer and society	Conduct themselves to uphold the professional and social obligations.
7	Environment and sustainability	Design the system with environment consciousness and sustainable development.
8	Ethics	Interact in industry, business and society in a professional and ethical manner.
9	Individual and team work	Function in a multidisciplinary team.
10	Communication	Proficiency in oral and written Communication.

PO #	Graduate Attribute	Programme Outcome
11	Project management and finance	Implement cost effective and improved system.
12	Life-long learning	Continue professional development and learning as a life-long activity.

PROGRAM SPECIFIC OUTCOMES (PSOs):

1. To create awareness on the solar energy, generation from solar thermal and SPV systems, distribution, consumption and computation of plant efficiency.
2. To quantify the emission mitigation for sustainable development through solar energy system.
3. To impart knowledge in various domains to identify research gaps and ideate innovations by simulation of solar energy systems using softwares such as MATLAB, ANSYS- CFX, Fluent, TRNSYS, PV-SYST, PVF-Chart, F-Chart, COMSOL Multiphysics.

PEO / PO Mapping:

PROGRAMME EDUCATIONAL OBJECTIVES	PROGRAMME OUTCOMES											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
I	✓	✓	✓	✓	✓				✓	✓	✓	✓
II	✓	✓	✓	✓	✓	✓						
III	✓	✓	✓	✓	✓	✓	✓				✓	✓
IV	✓	✓	✓	✓				✓	✓	✓	✓	
V	✓	✓	✓	✓	✓	✓	✓	✓				✓

MAPPING OF COURSE OUTCOME AND PROGRAMME OUTCOME

		Course Name	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
I YEAR	Sem 1	Thermodynamic Analysis of Energy Systems	✓	✓	✓	✓	✓		✓					✓
		Fluid Mechanics and Heat Transfer	✓	✓	✓	✓	✓		✓					✓
		Instrumentation for Energy Systems	✓	✓	✓	✓			✓					✓
		Physics of Solar Engineering	✓	✓	✓	✓	✓	✓	✓					
		Program Elective I (one from list of electives I)												
		Research Methodology and IPR	✓											
		Audit Course – I												
		Solar Thermal Laboratory -I	✓	✓		✓								
		Analysis and Simulation Laboratory for Solar Energy	✓	✓			✓							
	Sem 2	Solar Photovoltaic Technologies	✓	✓	✓	✓	✓	✓	✓				✓	✓
		Solar Thermal Technologies	✓	✓	✓	✓	✓	✓	✓				✓	✓
		Computational Fluid Dynamics for Energy Systems	✓	✓	✓	✓	✓		✓					✓
		Program Elective II												
		Program Elective III												
		Audit Course –II												
		Solar Thermal Laboratory -II	✓	✓		✓	✓							
		Solar Photovoltaic Laboratory	✓	✓		✓	✓							
		Mini Project with Seminar							✓	✓				
II YEAR	Sem 3	Program Elective IV												
		Program Elective V												
		Open Elective												
		Dissertation-I	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Sem 4	Dissertation-II	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

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M.E. (SOLAR ENERGY) (FULL – TIME)

REGULATIONS - 2019

CHOICE BASED CREDIT SYSTEM

CURRICULA AND SYLLABI FOR I TO IV SEMESTERS

SEMESTER I

SL. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.	EY5155	Thermodynamic Analysis of Energy Systems	PCC	3	1	0	4	4
2.	EY5152	Fluid Mechanics and Heat Transfer	PCC	3	1	0	4	4
3.	EY5153	Instrumentation for Energy Systems	PCC	3	0	0	3	3
4.	SY5101	Physics of Solar Engineering	PCC	3	0	0	3	3
5.	RM5151	Research Methodology and IPR	RMC	2	0	0	2	2
6.		Program Elective I	PEC	3	0	0	3	3
7.		Audit Course – I *	AC	2	0	0	2	0
PRACTICAL								
8.	SY5111	Solar Thermal Laboratory - I	PCC	0	0	4	4	2
9.	SY5112	Analysis and Simulation Laboratory for Solar Energy	PCC	0	0	4	4	2
			TOTAL	**19**	**2**	**8**	**29**	**23**

* Audit Course is optional.

SEMESTER II

SL. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.	SY5201	Solar Photovoltaic Technologies	PCC	3	0	0	3	3
2.	SY5202	Solar Thermal Technologies	PCC	3	0	0	3	3
3.	EY5251	Computational Fluid Dynamics for Energy Systems	PCC	3	1	0	4	4
4.		Program Elective II	PEC	3	0	0	3	3
5.		Program Elective III	PEC	3	0	0	3	3
6.		Audit Course – II*	AC	2	0	0	2	0
PRACTICALS								
7.	SY5211	Solar Thermal Laboratory -II	PCC	0	0	4	4	2
8.	SY5212	Solar Photovoltaic Laboratory	PCC	0	0	4	4	2
9.	SY5213	Mini Project with Seminar	EEC	0	0	4	4	2
			TOTAL	**17**	**1**	**12**	**30**	**22**

* Audit Course is optional.

SEMESTER III

SL. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.		Program Elective IV	PEC	3	0	0	3	3
2.		Program Elective V	PEC	3	0	0	3	3
3.		Open Elective	OEC	3	0	0	3	3
PRACTICAL								
4.	SY5311	Dissertation - I	EEC	0	0	12	16	6
			TOTAL	**9**	**0**	**12**	**25**	**15**

SEMESTER IV

SL. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
PRACTICAL								
1.	SY5411	Dissertation - II	EEC	0	0	24	12	12
			TOTAL	**0**	**0**	**24**	**12**	**12**

Total credits for the programme = 23 + 22 + 15 +12 = 72

PROGRAM CORE COURSES (PCC)

Sl. No.	Course Code	Course Title	Periods per week			Credits	Semester
			L	T	P		
1.	EY5155	Thermodynamic Analysis of Energy Systems	3	1	0	4	1
2.	EY5152	Fluid Mechanics and Heat Transfer	3	1	0	4	1
3.	EY5153	Instrumentation for Energy Systems	3	0	0	3	1
4.	SY5101	Physics of Solar Engineering	3	0	0	3	1
5.	SY5111	Solar Thermal Laboratory -I	0	0	4	2	1
6.	SY5112	Analysis and Simulation Laboratory for Solar Energy	0	0	4	2	1
7.	SY5201	Solar Photovoltaic Technologies	3	0	0	3	2
8.	SY5202	Solar Thermal Technologies	3	0	0	3	2
9.	EY5251	Computational Fluid Dynamics for Energy Systems	3	1	0	4	2
10.	SY5211	Solar Thermal Laboratory -II	0	0	4	2	2
11.	SY5212	Solar Photovoltaic Laboratory	0	0	4	2	2

PROGRAM ELECTIVE COURSES

SEMESTER I, ELECTIVE – I

SL. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
1.	SY5001	Materials for Solar Devices	PEC	3	0	0	3	3
2.	EY5154	Renewable Energy Systems	PEC	3	0	0	3	3
3.	EY5151	Energy Management and Environmental Benefits	PEC	3	0	0	3	3
4.	RA5071	Solar Refrigeration and Air Conditioning	PEC	3	0	0	3	3

SEMESTER II, ELECTIVE – II

SL. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
1.	SY5002	Solar Systems for Building Techniques	PEC	3	0	0	3	3
2.	EY5075	Energy Forecasting, Modeling and Project Management	PEC	3	0	0	3	3
3.	EY5081	Solar Energy Technologies	PEC	3	0	0	3	3
4.	SY5003	Solar Energy Appliances	PEC	3	0	0	3	3

SEMESTER II, ELECTIVE – III

SL. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
1.	EY5071	Advanced Energy Storage Technologies	PEC	3	0	0	3	3
2.	EY5074	Energy Efficient Buildings Design	PEC	3	0	0	3	3
3.	SY5004	Solar Power Generation Technologies and Policies	PEC	3	0	0	3	3

SEMESTER III, ELECTIVE – IV

SL. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
1.	EY5073	Electrical Drives and Controls	PEC	3	0	0	3	3
2.	EY5079	Power Electronics for Renewable Energy Systems	PEC	3	0	0	3	3
3.	SY5005	Solar Power Plants	PEC	3	0	0	3	3

SEMESTER III, ELECTIVE – V

SL. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
1.	SY5006	Solar Passive Architecture	PEC	3	0	0	3	3
2.	EY5076	Environmental Engineering and Pollution Control	PEC	3	0	0	3	3
3.	EY5080	Smart Grid	PEC	3	0	0	3	3
4.	SY5007	Solar Energy for Industrial Process Heating	PEC	3	0	0	3	3

RESEARCH METHODOLOGY AND IPR COURSES (RMC)

SL. NO.	COURSE CODE	COURSE TITLE	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
			L	T	P		
1.	RM5151	Research Methodology and IPR	2	0	0	2	2

OPEN ELECTIVE COURSES [OEC]

(Out of 6 Courses one Course must be selected)

SL. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
1.	OE5091	Business Data Analytics	OEC	3	0	0	3	3
2.	OE5092	Industrial Safety	OEC	3	0	0	3	3
3.	OE5093	Operations Research	OEC	3	0	0	3	3
4.	OE5094	Cost Management of Engineering Projects	OEC	3	0	0	3	3
5.	OE5095	Composite Materials	OEC	3	0	0	3	3
6.	OE5096	Waste to Energy	OEC	3	0	0	3	3

AUDIT COURSES (AC)

Registration for any of these courses is optional to students

SL. NO	COURSE CODE	COURSE TITLE	PERIODS PER WEEK			CREDITS
			L	T	P	
1.	AX5091	English for Research Paper Writing	2	0	0	0
2.	AX5092	Disaster Management	2	0	0	0
3.	AX5093	Sanskrit for Technical Knowledge	2	0	0	0
4.	AX5094	Value Education	2	0	0	0
5.	AX5095	Constitution of India	2	0	0	0
6.	AX5096	Pedagogy Studies	2	0	0	0
7.	AX5097	Stress Management by Yoga	2	0	0	0
8.	AX5098	Personality Development Through Life Enlightenment Skills	2	0	0	0
9.	AX5099	Unnat Bharat Abhiyan	2	0	0	0

EMPLOYABILITY ENHANCEMENT COURSES (EEC)

Sl. No.	Course Code	Course title	Periods per Week			Credits	Semester
			L	T	P		
1	SY5213	Mini Project with Seminar	0	0	4	2	2
2	SY5311	Dissertation - I	0	0	12	6	3
3	SY5411	Dissertation - II	0	0	24	12	4

EY5155	THERMODYNAMIC ANALYSIS OF ENERGY SYSTEMS	L	T	P	C
		3	1	0	4

OBJECTIVES:

1. To understand and apply the concept of availability and thermodynamic relations
2. To understand and calculate the behaviour of real gases and gas mixtures
3. To understand the applications of first and second law to chemically reacting systems
4. To learn various aspects of combustion chemistry
5. To use the concepts of advanced thermodynamics to combustion systems

UNIT – I AVAILABILITY ANALYSIS AND THERMODYNAMIC PROPERTY RELATIONS **12**

Reversible work – availability – irreversibility. Second law efficiency for a closed system and steady – state, control volume. Availability analysis of simple cycles. Thermodynamic potentials. Maxwell relations. Generalized relations for changes in entropy – internal energy and enthalpy – C_p and C_V. Clausius Clayperon equation, Joule – Thomson coefficient. Bridgeman tables for thermodynamic relations.

UNIT – II PROPERTIES OF REAL GAS AND GAS MIXTURES **12**

Different equations of state – fugacity – compressibility. Principle of corresponding States – Use of generalized charts for enthalpy and entropy departure. Fugacity coefficient, Lee – Kesler generalized three parameter tables. Fundamental property relations for systems of variable composition. Partial molar properties. Ideal and real gas mixtures.

UNIT – III CHEMICAL THERMODYNAMICS AND EQUILIBRIUM **12**

First and second law analysis of reacting systems - Adiabatic flame temperature - entropy change of reacting systems. Criterion for reaction equilibrium. Equilibrium constant for gaseous mixtures and evaluation of equilibrium composition.

UNIT – IV COMBUSTION CHEMISTRY **12**

Combustion of Hydrocarbon Fuels. Heat of reaction, combustion and formation. Stoichiometric, fuel rich and oxygen rich reactions. Heating value of fuels. Explosion limits, flames and flammability limits. Diffusion and premixed flames.

UNIT – V COMBUSTION PROCESSES AND COMBUSTION CHAMBERS **12**

Combustion in IC Engines and Gas turbines. Knocking and Detonation and control. Design principles of combustion chambers for IC Engines and Gas turbine. Arrangements of gas turbine combustion – comparative analysis.

TOTAL: 60 PERIODS

OUTCOMES:

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

1. Calculate the availability of the systems and cycles, and apply various thermodynamic relations
2. Predict the behavior of real gas and calculate the properties of gas mixtures
3. Apply first and second law to chemically reacting systems
4. Calculate the air fuel ratio, composition of combustion products and combustion limits
5. Apply the thermodynamic knowledge for analyzing the combustion process and combustion chamber design

REFERENCES:

1. Bejan, A., Advanced Engineering Thermodynamics, John Wiley and Cons, 1988.
2. Kalyan Annamalai, Ishwar K. Puri, Milind A. Jog., Advanced thermodynamics engineering, CRC press, 2011
3. Natarajan, E., Engineering Thermodynamics – Fundamentals and Applications, Anuragam Publications, 2014.
4. Kuo, K.K., Principles of Combustion, John Wiley and Sons, 2005
5. Kenneth Wark Jr., Advanced Thermodynamics for Engineers, McGraw – Hill Inc., 1995.

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.9	0.6	0.9	0.6	0.3	0.6	0.3	0.6	0.9	0.3	0.6	0.9	0.9	0.6	0.6
2	0.6	0.9	0.6	0.9	0.3	0.6	0.6	0.3	0.3	0.6	0.3	0.6	0.6	0.3	0.3
3	0.3	0.6	0.3	0.9	0.9	0.6	0.3	0.3	0.3	0.3	0.3	0.9	0.6	0.3	0.6
4	0.3	0.6	0.6	0.3	0.9	0.3	0.9	0.6	0.3	0.3	0.3	0.3	0.6	0.3	0.3
5	0.3	0.3	0.9	0.3	0.3	0.3	0.3	0.3	0.6	0.3	0.3	0.3	0.3	0.3	0.3

EY5152 FLUID MECHANICS AND HEAT TRANSFER

L	T	P	C
3	1	0	4

OBJECTIVES:

1. To make students familiarize with the application of conservation equations
2. To explain the incompressible and compressible fluid flow concepts
3. To inculcate the analysis of conduction and gas radiation heat transfer
4. To provide the details of turbulent forced convective heat transfer
5. To impart the knowledge of design of single phase and multi-phase heat exchangers

UNIT – I BASIC EQUATION, POTENTIAL FLOW AND BOUNDARY LAYER THEORY **12**

Three dimensional forms of governing equations – Mass, Momentum and Energy equations 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 RADIATION HEAT TRANSFER **12**

Governing Equation and Boundary conditions, Extended surface heat transfer, Transient conduction – Use of Heisler-Grober charts, Conduction with moving boundaries, Stefan and Neumann problem - Gas Radiation.

UNIT – IV TURBULENT FORCED CONVECTIVE HEAT TRANSFER **12**

Turbulence theory – mixing length concept – turbulence model – k Є model – analogy between heat and momentum transfer – Reynolds, Colburn, Prandtl turbulent flow in a tube – high speed flows.

UNIT – V PHASE CHANGE HEAT TRANSFER AND HEAT EXCHANGER 12

Condensation on bank of tubes – boiling – pool and flow boiling, Heat exchanger – Є – NTU approach and design procedure – compact heat exchanger.

TOTAL: 60 PERIODS

OUTCOMES:

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

1. Identify, formulate and analyze the governing equations for various engineering applications
2. Learn the flow concepts of incompressible and compressible flow.
3. Solve the conduction and gas radiation heat transfer problems.
4. Understand the turbulent forced convective heat transfer
5. Design a heat exchanger as per the industrial needs.

REFERENCES:

1. **Yunus A Cengel and John M Cimbala**, "Fluid Mechanics Fundamentals and Applications," TMH, Ltd., Second Edition, 2006.
2. **Shiv Kumar**, "Fluid Mechanics Basic Concepts & Principles " Ane Books Pvt. Ltd, Second Edition, 2011
3. **Venkateshan S P.**, "Heat Transfer " Ane Books Pvt. Ltd, 2011
4. **Holman J P,** "Heat Transfer", TMH Ltd., Ninth Edition, 2010.
5. **Ozisik M N.,** "Heat Transfer – A Basic Approach", McGraw Hill Co, 1985.

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.9	0.9	0.9	0.9	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.9
2	0.9	0.9	0.9	0.9	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.9
3	0.9	0.9	0.9	0.9	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.9
4	0.9	0.9	0.9	0.9	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.9
5	0.9	0.9	0.9	0.9	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.9

EY5153 INSTRUMENTATION FOR ENERGY SYSTEMS L T P C

3 0 0 3

OBJECTIVES:

1. To impart knowledge about characteristics of measurement system and statistical analysis of measured data.
2. To make students conversant with the electrical measurements and signal conditioning circuits.
3. To provide insight into the digital measuring techniques of physical quantities and Solar instruments.
4. To make the students get acquainted with the measurement of thermo-physical properties and air pollutants.
5. To inculcate skills in the design and development of measurement and control systems.

UNIT – I MEASUREMENT SYSTEM: CHARACTERISTICS AND STATISTICAL ANALYSIS 9

Introduction to measurement system, Errors in Measurement, Static and Dynamic characteristics of transducers, Statistical analysis of experimental data – Uncertainty analysis, Regression analysis, Design of experiments – Full and Half factorial design.

UNIT – II ELECTRICAL MEASUREMENTS AND SIGNAL CONDITIONING 9

Voltage, Current, Power, Energy, Time and Frequency measurement, Frequency Counter, Signal conditioning Circuits: Wheatstone bridge – Differential Amplifier – V to I Converter, I to V Converter, Integrator, Differentiator, Instrumentation Amplifier, Attenuators and Filters, DAC, ADC, PID Controller.

UNIT – III DIGITAL MEASUREMENT OF PHYSICAL QUANTITIES 9

Digital measuring techniques of Displacement, Temperature, Pressure, Force, Torque, Vibration, Acceleration, Velocity, Level, Flow, Thermal and Nuclear Radiation. Solar instruments:Pyrheliometers – Pyranometers– Pyrheliometers – Albedometers – Pyrradiometers – Pyrgeometers – Net Pyrradiometers – Sunphotometers.

UNIT – IV MEASUREMENT OF THERMO-PHYSICAL PROPERTIES AND AIR POLLUTANTS 9

Measurement of Thermal Conductivity – Solids, Liquids and Gas, Viscosity, Gas Diffusion. Calorimetry – Bomb Calorimeter – Continuous flow Calorimeter. Measurement of Heat Transfer, Humidity, Heat flux, pH, Air pollution Sampling and Measurement – Particulate Sampling techniques – Measurement of Sulphur Dioxide, Combustion products, Opacity and Odour.

UNIT – V CONTROL SYSTEMS 9

Introduction to Arduino and Raspberry Pi – Interfacing with I/O devices of system: Sensors, Display devices, Stepper and Servo motors. Measurement by Data Acquisition System. Introduction to Internet of Things (IoT) – Application of IoT with Raspberry Pi for Process monitoring and control – Energy management. Application of PID controller in PV and Energy systems. Application of Smart Sensors and Intelligent instrumentation and Control.

TOTAL: 45 PERIODS

OUTCOMES:

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

1. Analyze and evaluate the uncertainties in measurement data.
2. Identify appropriate sensors for measuring electrical quantities and signal conditioning circuits.
3. Explain the digital measurement techniques of physical quantities.
4. Implement the measurement of thermo-physical properties and air pollutants.
5. Design and develop the appropriate measurement and control system for an application.

REFERENCES:

1. Barney G.C., “Intelligent instrumentation: microprocessor applications in measurement and control”, Prentice Hall, 1988.
2. Bell C., “Beginning Sensor Networks with Arduino and Raspberry Pi”, Apress, 2013.
3. Doebelin E. and ManikD.N., “Doebelin’s Measurement Systems”, Tata McGraw Hill, 2011.
4. George, B., Roy, J.K., Kumar, V.J., Mukhopadhyay, S.C., “Advanced Interfacing Techniques for Sensors”, Springer, 2017.
5. Holman J.P., “Experimental methods for Engineers”, Tata McGraw Hill, 2007.

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.9	0.9		0.9										0.9	
2	0.9		0.6						0.9					0.9	
3	0.9		0.9											0.9	
4	0.9		0.9				0.6							0.9	
5	0.9		0.9	0.9	0.9				0.9			0.9			0.9

SY5101	PHYSICS OF SOLAR ENGINEERING	L	T	P	C
		3	0	0	3

OBJECTIVES:

1. To impart the knowledge on the basics of solar energy and laws related to it.
2. To understand the physics of sun, angles and solar time.
3. To study the principle operations, types and applications of solar cells.
4. To provide insights of solar thermal collectors and basic solar cycles.
5. To understand the concepts of various energy storage technologies.

UNIT – I INTRODUCTION 10

Basics of solar energy - Brief History of solar energy utilization - Various approaches of utilizing solar energy - Blackbody radiation - Relation between radiation field energy density and radiation spectrum - Planck's formula in energy unit - Maximum spectral density - Planck's formula in wavelength unit - Wien displacement law - Stefan - Boltzmann law - Photoelectric effect - Einstein's theory of photons - Einstein's derivation of the black-body formula.

UNIT – II THE PHYSICS OF THE SUN & ATMOSPHERIC INTERACTION 10

The structure of the Sun - Basic parameters of the Sun - Measurement of the solar constant - Rotation and orbital motion of the Earth around the Sun - Solar time, sidereal time, universal standard time, local standard time - Equation of time - Intensity of sunlight on an arbitrary surface at any time - Interaction with the atmosphere - Air mass - Rayleigh and Mie scattering - Absorption.

UNIT – III SOLAR CELLS 10

Formation of a PN – junction - Space charge and internal field - Quasi - Fermi levels - The Shockley diode equation - Structure of a solar cell - The solar cell equation - Fill factor and maximum power - Various electron-hole pair recombination mechanisms - Crystalline silicon solar cells: Mono and Multi-crystalline, Thin film solar cells: CIGS, CdTe, a-Si and Tandem solar cells, Multi-junction cells, Emerging PV: DSSC - Organic solar cells – Perovskite – Quantum Dots.

UNIT – IV SOLAR THERMAL COLLECTORS 9

Solar flat plate collector – Concentrating collectors – Concentration ratio - Three types of imaging optics: trough or linear collectors, central receiver power tower with heliostats, and parabolic dish concentrator with duel axis tracking - Solar thermal electricity using Stirling engine or Ranking engine - Solar photovoltaics with concentration.

UNIT – V ENERGY STORAGE 6

Necessity of storage for solar energy - Chemical energy storage - Thermal energy storage - Thermal Flywheels - Compressed air energy storage- Rechargeable batteries.

TOTAL: 45 PERIODS

OUTCOMES:

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

1. Enumerate the basic laws related to the solar radiation.
2. Predict the solar time due to the motion of the earth with respect to sun.
3. Provide accurate diagrams of solar cells and be able to classify solar cells.
4. Formulate scientific questions about the imaging type concentrating collectors.
5. Identify and classify the different energy storage techniques.

REFERENCES:

1. Duffie, J.A., and Beckman, W.A. Solar Energy Thermal Process - 4th Edition (2013), John Wiley and Sons, New York, ISBN: 978-0-470-87366-3, Solar Energy Laboratory, University of Wisconsin-Madison, pp. 944.
2. M. Stix, The Sun, An Introduction, Second Edition, Springer 2002.
3. Jenny Nelson, The Physics of Solar Cells. Imperial College Press, 2003
4. Chetan Singh Solanki, Solar Photovoltaics: Fundamentals, Technologies and Applications (2011), 2nd edition, PHI Publications, pp. 512.
5. Sukhatme S.P. J K Nayak, Solar Energy, Tata McGraw Hills P Co., ISBN: 9789352607112, 4th Edition, 2017, pp. 568.
6. C. Julian Chen, Physics of Solar Energy (2011), ISBN: 978-1-118-04832-0, pp. 352.

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.9	0.9	0.3	0.3	0.3	0.3						0.3			
2	0.9	0.9	0.6	0.6	0.6	0.6	0.3					0.3			
3	0.9	0.9	0.9	0.9	0.9	0.6	0.6					0.3			
4	0.9	0.9	0.9	0.9	0.9	0.6	0.6					0.3			
5	0.6	0.6	0.9	0.6	0.3	0.6	0.6								

RM5151 RESEARCH METHODOLOGY AND IPR L T P C
2 0 0 2

COURSE OBJECTIVES:

To impart knowledge and skills required for research and IPR:

- Problem formulation, analysis and solutions.
- Technical paper writing / presentation without violating professional ethics
- Patent drafting and filing patents.

UNIT I RESEARCH PROBLEM FORMULATION 6

Meaning of research problem- Sources of research problem, criteria characteristics of a good research problem, errors in selecting a research problem, scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, necessary instrumentations

UNIT II LITERATURE REVIEW 6

Effective literature studies approaches, analysis, plagiarism, and research ethics.

UNIT III TECHNICALWRITING /PRESENTATION 6

Effective technical writing, how to write report, paper, developing a research proposal, format of research proposal, a presentation and assessment by a review committee.

UNIT IV INTRODUCTION TO INTELLECTUAL PROPERTY RIGHTS (IPR) 6

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

UNIT V INTELLECTUAL PROPERTY RIGHTS (IPR) 6

Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases.Geographical Indications. New Developments in IPR: Administration of Patent System, IPR of Biological Systems, Computer Software etc.

Traditional knowledge Case Studies, IPR and IITs.

TOTAL: 30 PERIODS

COURCE OUTCOMES:

1. Ability to formulate research problem
2. Ability to carry out research analysis
3. Ability to follow research ethics
4. Ability to understand that today's world is controlled by Computer, Information Technology, but tomorrow world will be ruled by ideas, concept, and creativity
5. Ability to understand about IPR and filing patents in R & D.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓										
CO2	✓											
CO3	✓							✓				
CO4	✓				✓							
CO5	✓					✓						✓

REFERENCES:

1. Asimov, "Introduction to Design", Prentice Hall, 1962.
2. Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd ,2007.
3. Mayall, "Industrial Design", McGraw Hill, 1992.
4. Niebel, "Product Design", McGraw Hill, 1974.
5. Ranjit Kumar, 2nd Edition, "Research Methodology: A Step by Step Guide for beginners" 2010

SY5111 SOLAR THERMAL LABORATORY - I

L	T	P	C
0	0	4	2

OBJECTIVES:

1. To provide practical knowledge on various solar thermal systems
2. To evaluate the thermal performance of solar thermal systems

LIST OF EXPERIMENTS

1. Solar Radiation Measurements
2. Thermo-Syphon Solar Water Heater
3. Forced Convection Solar Water Heater
4. Wind load effect on Thermo-Syphon Solar Water Heater
5. Wind load effect on Forced Convection Solar Water Heater
6. Effect of inclination angle on the performance of solar water heater
7. Serpentine solar water heater
8. Forced convection Solar air collector
9. Natural convection solar air collector
10. Solar Box Cooker
11. Solar Box cooker with reflector
12. Thermal Energy Storage assisted Solar Box Cooker

TOTAL: 60 PERIODS

OUTCOMES:

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

1. Measure the solar radiation using various measuring instruments
2. Assess the thermal behavior of solar systems.

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.6	0.3		0.9									0.6	0.3	
2	0.6	0.3		0.9									0.6	0.3	

SY5112 ANALYSIS AND SIMULATION LABORATORY FOR SOLAR ENERGY

L	T	P	C
0	0	4	2

OBJECTIVES:

1. To provide a platform to learn and get familiar with transient system simulation tool
2. To learn the transient analysis simulation software for predicting the performance of solar system components

LIST OF EXPERIMENTS

1. Performance study on different types of solar flat plate collector
2. Performance study on stand-alone solar PV panel.
3. Detailed comparative study between horizontal and vertical sensible storage tank for uniform and non-uniform losses.
4. Performance study on thermo-syphon solar collector with internal storage.
5. Optimization of solar collector integrated with stratified thermal storage tank for hot water applications.
6. Performance study on linear parabolic concentrator using different heat transfer fluids.
7. Performance Study of solar flat plate collector including shading effects.
8. Performance study on one-ton solar refrigeration system.
9. Optimize the solar air heating system for drying application
10. Performance study on packed bed sensible thermal energy storage unit
11. Performance study on PVT solar collector using air and water as a heat transfer fluids .
12. Performance Study of solar PV panel including shading effects.

TOTAL: 60 PERIODS

OUTCOMES:

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

1. Use modern engineering software tools to analyze the transient behavior of various solar systems.
2. Analyze the various parameters influencing the performance of solar systems

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.6	0.6			0.9										0.9
2	0.6	0.6			0.9										0.9

SY5201	SOLAR PHOTOVOLTAIC TECHNOLOGIES	L	T	P	C
		3	0	0	3

OBJECTIVES:

1. To explain basics of solar photovoltaic systems.
2. To know in depth of its types and design of various PV-interconnected systems.
3. To Learn about the grid connected PV systems
4. To impart knowledge on need and type of Hybrid systems
5. To design the System Components for different PV Applications

UNIT – I INTRODUCTION TO SOLAR PHOTOVOLTAICS 10

Structure and working of Solar Cells - Types, Electrical properties and Behaviour of Solar Cells – Cell properties and design - PV Cell Interconnection and Module Fabrication - Electrical characteristics of the solar cell - equivalent circuit - Effects of temperature, irradiation and series/shunt resistances on the open-circuit voltage and short-circuit current - PV generators, shadow effects – Blocking and bypass diodes - hot spot problem in a PV module.

UNIT – II STAND ALONE PV SYSTEMS 10

Schematics and Components - Balance of system components for DC and/or AC Applications - Maximum power point tracking (MPPT) algorithms - Interfacing PV modules to loads - Direct connection of loads to PV modules - Connection of PV modules to a battery and load together - Typical applications for lighting, water pumping etc.

UNIT – III GRID CONNECTED PV SYSTEMS 10

Schematics and Components - Balance of system Components - Interface Components – Net metering - Feasible operating region of inverter at different power factor - Active power filtering with real power injection.

UNIT – IV HYBRID SYSTEMS 7

Need for Hybrid Systems - Range and type of Hybrid systems - Case studies of Diesel-PV, Wind-PV, Microhydel-PV, Biomass-Diesel systems, Electric and hybrid electric vehicles - Comparison and selection criteria for a given application.

UNIT – V DESIGN OF PV SYSTEMS 8

Design of System Components for different PV Applications - Sizing and Reliability - Modeling and simulation of stand-alone and grid-connected PV systems – Case Studies.

TOTAL: 45 PERIODS

OUTCOMES:

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

1. Apply principle of evidence-based photovoltaic technology
2. Provide accurate schematic of stand-alone PV systems and BOS
3. Provide accurate schematic of grid-connected PV systems and BOS
4. Select appropriate hybrid system for different applications
5. Design and simulate the stand-alone and grid connected system.

REFERENCES:

1. A. Goetzberger, V. U. Hoffmann, Volker Uwe, Photovoltaic Solar Energy Generation (2005), Springer-Verlag Berlin Heidelberg, ISBN: 978-3-540-23676-4, pp.234.
2. Jenny Nelson, The Physics of Solar Cells. Imperial College Press, 2003
3. Chetan Singh Solanki, Solar Photovoltaics: Fundamentals, Technologies and Applications (2011), 2nd edition, PHI PHI Learning Pvt. Ltd, pp. 512.
4. T. Markvart, Solar Electricity (2000), John Wiley & Sons, ISBN: 978-0-471-98852-6, pp.298.
5. R. A. Messenger and Amir Abtahi, Photovoltaic Systems Engineering (2017), 4th Edition, CRC Press, Boca Raton, ISBN: 9781498772778, pp. 504.

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.9	0.9	0.6	0.6	0.9	0.6	0.6					0.3			
2	0.9	0.9	0.9	0.9	0.9	0.9	0.6					0.3			
3	0.9	0.9	0.9	0.9	0.9	0.9	0.6					0.3			
4	0.9	0.6	0.9	0.9	0.9	0.9	0.6					0.3			
5	0.9	0.9	0.9	0.9	0.9	0.9	0.6								

SY5202 SOLAR THERMAL TECHNOLOGIES L T P C
3 0 0 3

OBJECTIVES:

1. To clarify impression of various solar thermal energy collectors
2. To delineate the other applications and the devices used to collect solar energy
3. To study the various types and configurations of solar space conditioning system
4. To learn the various solar applications.
5. To summarize the basic economics of solar energy collection system.

UNIT – I SOLAR COLLECTORS 9

Collectors: Flat plate: Water, Air - Evacuated tube – Concentrated – Construction – Function - Suitability – Comparison – Design of Storage Tank - Solar Fluids.

UNIT – II SOLAR WATER HEATING SYSTEMS 8

Integral Collector Storage System - Thermosyphon System - Open Loop, Drain Down, Drain Back, Antifreeze Systems - Refrigerant Solar Water Heaters - Solar Heated Pools - Solar Heated Hot Tubs and Spas.

UNIT – III SOLAR SPACE CONDITIONING SYSTEMS 9

Liquid Type Solar Heating System With / Without Storage - Heat Storage Configurations – Heat Delivery Methods - Air-Type Solar Heating Systems - Solar Refrigeration and Air Conditioning.

UNIT – IV OTHER SOLAR APPLICATIONS 9

Solar Cooking – Distillation - Desalination - Solar Ponds – Solar Passive Architecture – Solar Drying – Solar Chimney.

UNIT – V SOLAR ECONOMICS 10

Application of economic methods to analyze the feasibility of solar systems to decide project / policy alternatives - Net energy analysis - and cost requirements for active and passive heating and cooling - for electric power generation - and for industrial process-heating.

Economics – Fixed and variable cost - Payback period - Net Present Value - Internal Rate of Return - Carbon credit – Embodied energy analysis.

TOTAL: 45 PERIODS

OUTCOMES:

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

1. Explain the technical and physical principles of different solar collectors
2. Measure and evaluate different solar energy technologies through knowledge of the physical function of the devices
3. Articulate the technical and economic fundamentals of solar thermal energy conversion useful to society and industry
4. Describe the spectrum of possible solar thermal technologies to assist industrial processing or power production
5. Communicate technological and socio-economic issues around solar energy in a concise and an accessible way to a target group with basic technical skills.

REFERENCES:

1. Duffie, J.A., and Beckman, W.A. Solar Energy Thermal Process - 4th Edition (2013), John Wiley and Sons, New York, ISBN: 978-0-470-87366-3, Solar Energy Laboratory, University of Wisconsin-Madison, pp. 944.
2. H P Garg, M Dayal, G Furlan, Physics and Technology of Solar Energy- Volume I: Solar Thermal Applications, Springer, 2007.
3. Sukhatme S.P. J K Nayak, Solar Energy, Tata McGraw Hills P Co., ISBN: 9789352607112, 4th Edition, 2017, pp. 568.
4. Charles Christopher Newton - Concentrated Solar Thermal Energy- Published by VDM Verlag, 2008.
5. H.P.Garg, S.C.Mullick, A.K.Bhargava, D.Reidal, Solar Thermal Energy Storage Springer, 2005.

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.9	0.9	0.9	0.9	0.3	0.6	0.6					0.3			
2	0.9	0.9	0.9	0.9	0.3	0.6	0.6					0.3			
3	0.9	0.9	0.9	0.9	0.3	0.6	0.6					0.3			
4	0.9	0.9	0.6	0.6	0.3	0.9	0.6					0.3			
5	0.9	0.9			0.3	0.3					0.3				

EY5251 COMPUTATIONAL FLUID DYNAMICS FOR ENERGY SYSTEMS

L	T	P	C
3	1	0	4

OBJECTIVES:

1. To make students familiarize with the computational analysis
2. To explain the numerical analysis of solving of steady and unsteady diffusion heat transfer
3. To explain the numerical analysis of solving of convection-diffusion heat transfer
4. To provide the details of discretization of incompressible flow governing equations
5. To impart the knowledge of turbulence modelling

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 MODELLING 12

Kolmogorov's Theory - Turbulence - Algebraic Models, One equation model & k – ε, k – ω models - Standard and High and Low Reynolds number models.

TOTAL: 60 PERIODS

OUTCOMES:

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

1. Know the differences between various discretization techniques.
2. Learn the finite volume based numerical method for solving diffusion heat transfer problems.
3. Learn the finite volume based numerical method for solving convection-diffusion heat transfer problems.
4. Understand the discretization of incompressible flow governing equations
5. 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, New Delhi, 1995.

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.9	0.6	0.3									0.6	0.9	0.6	
2	0.9	0.6	0.3									0.6	0.9	0.6	
3	0.9	0.6	0.3									0.6	0.9	0.6	
4	0.9	0.6	0.3									0.6	0.9	0.6	
5	0.9	0.6	0.3									0.6	0.6	0.6	

SY5211 SOLAR THERMAL LABORATORY - II

L	T	P	C
0	0	4	2

OBJECTIVES:

1 To provide practical knowledge on various solar thermal concentrating collectors
2 To evaluate the thermal performance of various solar thermal systems

LIST OF EXPERIMENTS

1. Evacuated tube solar collector
2. Solar dish collector
3. Compound parabolic collector connected in series
4. Compound parabolic collector connected in parallel
5. Parabolic trough collector
6. Scheffler Dish solar concentrator
7. Heat pipe solar collector
8. PVT air collector
9. PVT air collector integrated greenhouse dryer
10. Solar still
11. Integrated PVT Solar still
12. Thermal Energy Storage assisted Solar still

TOTAL: 60 PERIODS

OUTCOMES:

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

1. Assess the thermal performance of solar concentrating collectors
2. Demonstrate the experiment of various integrated solar systems

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.6	0.3		0.9									0.6	0.3	
2	0.6	0.3		0.9									0.6	0.3	

SY5212 SOLAR PHOTOVOLTAIC LABORATORY L T P C

0 0 4 2

OBJECTIVES:

1. To construct a practical knowledge on stand-alone solar PV systems.
2. To construct a practical knowledge on grid tide solar PV systems.

LIST OF EXPERIMENTS

1. Study on Solar Cell Characteristics
2. Testing of SPV Stand-alone Systems
3. Testing on Solar Home Systems
4. Optimization of SPV Systems with Load Resizing
5. Testing of Simple Hybrid Systems
6. Testing of Solar PV Water Pumps
7. Studies on Charging and Discharging Cycles of the batteries.

TOTAL: 60 PERIODS

OUTCOMES:

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

1. The performance of the Solar PV cell under various specified operating temperature ranges and will be able to relate it with nominal values.
2. The various radiation measuring instruments related to solar photovoltaics.

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.6		0.9	0.3											
2	0.6		0.6	0.9											

SY5001 MATERIALS FOR SOLAR DEVICES L T P C

3 0 0 3

OBJECTIVES:

1. To comprehend the materials that has been implicated in various forms of solar energy sources and its storages.
2. To educate the structure-property relationship and appreciate novel developments in the materials.
3. To explain the concept and the diverse materials used for solar devices.
4. To explicate in depth knowledge of about solar cells, thermal energy storage and electrical energy storages
5. To gather some idea of system balance and analysis with reference to its cost.

UNIT – I MATERIALS FOR SOLAR COLLECTORS 9

Collector Materials for Low, Medium and High Temperature Applications - Glazing Materials, Optical Materials - Absorber Coatings, Insulations, Desiccants, Use of Plastics - Reliability and Durability of Solar Collectors - Environmental Degradation of Low Cost Solar Collectors.

UNIT – II MATERIALS FOR SOLAR CELLS 9

Crystalline Structure - Fundamental Principles of Energy Bands – Band Gap – Types of Semiconductors – Doping and influence of impurities on energy levels – Element and Compound Semiconductors – Structure of Silicon solar cell – Fabrication and Optimization of solar cells – Amorphous silicon solar cells.

UNIT – III THIN FILM AND NOVEL SOLAR CELL MATERIALS 9

Cadmium Telluride, Galium-Arsenic, GaInP / GaAs / Ge - Thin Film, Single Crystalline, Polycrystalline Materials - Multi Junction and Tandem Junction Solar Cells - Low Cost and High Efficiency Materials - Conversion Efficiency of Solar Cells. – Perovskite solar cells – Dye-sensitized Organic solar cells.

UNIT – IV ENERGY STORAGE MATERIALS 9

Thermal Storage Concepts - Materials for Sensible and Latent Heat Energy Storage. Organic, Inorganic Eutectic Materials, Materials for Low and High Temperature Storage Applications. Chemical storage Concepts - Rechargeable Batteries – Types, Operating range, Comparison and suitability for various applications - Super Capacitors.

UNIT – V BALANCE OF SYSTEM MATERIALS & COST ANALYSIS 9

Functional requirements of other materials for components like Invertors, Charge Controllers, Wires, Pipes, Valves, etc. and identification of suitable materials - Simple Cost Analysis for alternative selection of materials - Case studies.

TOTAL: 45 PERIODS

OUTCOMES:

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

1. The students will get fundamental understanding on principles of materials used in solar cells.
2. The students will be able to understand the structure-property relationship and appreciate novel developments in the materials.
3. To explain the concept and the diverse materials used for solar devices.
4. To explicate in depth knowledge of about solar cells, thermal energy storage and electrical energy storages.
5. To gather some idea of system balance and analysis with reference to its cost.

REFERENCES:

1. Ibrahim Dincer and Marc A Rosan, Thermal Energy Storage: Systems and Applications, John Wiley, 2003.
2. Sukhatme and Nayak , Solar Energy: Principles Of Thermal Collection & Storage, Tata McGrawHill, 2008
3. Nelson, J, The Physics of Solar Cells, Imperial College Press, 2003
4. Jef Poortmans and Vladimir Arkhipov, Thin Film Solar Cells, John Wiley and Sons, 2008. Thomas Markvart, Solar Electricity, John Wiley and Sons, 2007
5. A.R. Jha, Solar Cell Technology and Applications, Aurbach Publications, 2010.

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.6	0.6	0.9	0.3	0.3	0.6	0.3						0.3	0.3	0.6
2	0.6	0.9	0.9	0.6	0.9	0.6							0.6	0.6	0.9
3	0.6	0.9	0.9	0.6	0.9								0.6	0.9	0.9
4	0.9	0.9	0.9	0.6	0.9		0.6						0.9	0.9	
5	0.3	0.9	0.9	0.3							0.9		0.6	0.9	

EY5154	RENEWABLE ENERGY SYSTEMS	L	T	P	C
		3	0	0	3

OBJECTIVES:

1. To know the Indian and global energy scenario
2. To learn the various solar energy technologies and its applications.
3. To educate the various wind energy technologies.
4. To explore the various bio-energy technologies.
5. To study the ocean and geothermal technologies.

UNIT – I ENERGY SCENARIO 9

Indian energy scenario in various sectors – domestic, industrial, commercial, agriculture, transportation and others – Present conventional energy status – Present renewable energy status-Potential of various renewable energy sources-Global energy status-Per capita energy consumption - Future energy plans

UNIT – II SOLAR ENERGY 9

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

UNIT – III WIND ENERGY 9

Wind data and energy estimation – Betz limit - Site selection for windfarms – characteristics - Wind resource assessment - Horizontal axis wind turbine – components - Vertical axis wind turbine – Wind turbine generators and its performance – Hybrid systems – Environmental issues - Applications.

UNIT – IV BIO-ENERGY 9

Bio resources – Biomass direct combustion – thermochemical conversion - biochemical conversion-mechanical conversion - Biomass gasifier - Types of biomass gasifiers - Cogeneration –- Carbonisation – Pyrolysis - Biogas plants – Digesters –Biodiesel production – Ethanol production - Applications.

UNIT – V OCEAN AND GEOTHERMAL ENERGY 9

Small hydro - Tidal energy – Wave energy – Open and closed OTEC Cycles – Limitations – Geothermal energy – Geothermal energy sources - Types of geothermal power plants – Applications - Environmental impact.

TOTAL: 45 PERIODS

OUTCOMES:

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

1. Know the Indian and global energy scenario
2. Learn the various solar energy technologies and its applications.
3. Have knowledge in the various wind energy technologies.
4. Explore the various bio-energy technologies.
5. Learn the ocean and geothermal technologies.

REFERENCES:

1. Godfrey Boyle, “Renewable Energy, Power for a Sustainable Future”, Oxford University Press, U.K., 2012.
2. Rai.G.D., “Non-Conventional Energy Sources”, Khanna Publishers, New Delhi, 2014.
3. Sukhatme.S.P., “Solar Energy: Principles of Thermal Collection and Storage”, Tata McGraw Hill Publishing Company Ltd., New Delhi, 2009.
4. Tiwari G.N., “Solar Energy – Fundamentals Design, Modelling and applications”, Alpha Science Intl Ltd, 2015.
5. Twidell, J.W. & Weir A., “Renewable Energy Resources”, EFNSpon Ltd., UK, 2015.

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.3	0.3	0.3	0.3	0.3	0.6	0.9	0.6	0.6	0.3	0.3	0.9	0.6	0.3	0.3
2	0.9	0.6	0.6	0.3	0.3	0.3	0.9	0.3	0.3	0.3	0.6	0.9	0.6	0.3	0.6
3	0.9	0.6	0.9	0.6	0.6	0.3	0.9	0.3	0.3	0.3	0.3	0.9	0.3	0.3	0.3
4	0.6	0.6	0.6	0.3	0.6	0.3	0.9	0.3	0.3	0.3	0.6	0.9	0.6	0.6	0.3
5	0.6	0.3	0.6	0.3	0.6	0.3	0.9	0.3	0.3	0.3	0.3	0.9	0.6	0.3	0.3

EY5151 **ENERGY MANAGEMENT AND ENVIRONMENTAL BENEFITS** **L T P C 3 0 0 3**

OBJECTIVES:

1. To create awareness on the energy scenario of India with respect to world
2. To learn the methodology adopted for an energy audit
3. To appreciate the concepts adopted in project management
4. To study the different techniques adopted for financial appraisal of a project
5. To Comprehend the impact of energy on environment

UNIT – I ENERGY SCENARIO 9

Comparison of energy scenario – India and World (energy sources, generation mix, consumption pattern, T&D losses, energy demand, per capita energy consumption) – energy pricing – energy security - energy conservation and its importance - Energy Conservation Act 2001

UNIT – II ENERGY MANAGEMENT 9

Energy audit - need – types – methodology – barriers - analysis on energy costing and sharing - bench marking - fuel and energy substitution – billing parameters in TANGEDCO – demand side management - instruments for energy audit – energy monitoring and targeting – CUSUM - energy labelling

UNIT – III PROJECT MANAGEMENT 9

Four Basic Elements of Project Management - Project Management Life Cycle - Steps in Project Management - Project Definition and Scope, Technical Design, Financing, Contracting, Implementation Techniques (Gantt Chart, CPM and PERT) and Performance Monitoring

UNIT – IV FINANCIAL MANAGEMENT 9

Investment appraisal for energy conservation projects - Financial analysis techniques -Simple pay back period, Return on investment, Net present value, Internal rate of return - Cash flows - Risk and sensitivity analysis: micro and macro factors - Financing options - energy performance contracts - ESCOs.

UNIT – V ENERGY AND ENVIRONMENT 9

Greenhouse effect and the carbon cycle - current evidence and future effects of climate change - Global Environmental Concerns - United Nations Framework Convention on Climate Change (UNFCC), Kyoto Protocol, Conference of Parties (COP), Emissions trading (ET), Joint implementation (JI), Clean Development Mechanism (CDM), Prototype Carbon Fund (PCF), Sustainable Development

TOTAL: 45 PERIODS

OUTCOMES:

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

1. Recognize the importance of energy conservation and suggest measures for improving per capita energy consumption
2. Analyse the energy sharing and cost sharing pattern of fuels used in industries
3. Apply Gantt Chart, CPM and PERT in energy conservation projects
4. Evaluate the techno-economics of a project adopting discounting and non-discounting cash flow techniqes
5. Assess the sources of additional revenue generation for energy conservation projects adopting UNFCC

REFERENCES:

1. Energy Manager Training Manual (4Volumes) available at http://www.em-ea.org/gbook1.asp, a website administered by Bureau of Energy Efficiency (BEE), a statutory body under Ministry of Power, Government of India.2004.
2. L.C. Witte, P.S. Schmidt, D.R. Brown, “Industrial Energy Management and Utilisation” Hemisphere Publ, Washington, 1988.
3. W.C. turner, “Energy Management Hand book” Wiley, New York, 1982
4. W.R. Murphy and G. McKay “Energy Management” Butterworths, London 1987
5. Eastop.T.D& Croft D.R, Energy Efficiency for Engineers and Technologists,.Logman Scientific & Technical, ISBN-0-582-03184, 1990.

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.9						0.6					0.3	0.9	0.6	0.3
2	0.9	0.6	0.6	0.6	0.3	0.3	0.6				0.6	0.6	0.6	0.9	
3	0.3	0.3	0.3	0.3	0.6			0.3	0.6		0.9				0.9
4	0.3	0.3		0.3	0.3			0.3	0.3		0.9	0.6		0.6	
5	0.3					0.6	0.9	0.3			0.6	0.3	0.9		

RA5071 SOLAR REFRIGERATION AND AIR-CONDITIONING

L	T	P	C
3	0	0	3

COURSE OBJECTIVES:

1. To impart the knowledge on thermodynamic cycles.
2. To provide thermal aspects on solar cooling.
3. To teach the students to have a broad understanding on absorption chillers.
4. To teach the students on modeling of solar refrigeration system.
5. To learn about economics in solar cooling systems.

UNIT – I INTRODUCTION **9**

Carnot cycle – Refrigerator – Heat Pump – Heat Transformer, Refrigerants – Types and historical developments – Environmental impacts - Thermodynamic Processes.

UNIT – II SOLAR COOLING **9**

Types of solar cooling systems – Solar collectors and storage systems for solar refrigeration and air-conditioning – Jet ejector solar cooling systems - Fuel assisted solar cooling systems – Solar thermo acoustic cooling and hybrid air-conditioning - Solar desiccant cooling systems – Advanced solar cooling systems.

UNIT – III ABSORPTION COOLING 9

Basics of absorption cooling - Principle of absorption cooling - Solar operation of vapour absorption refrigeration cycle - Open cycle absorption / desorption solar cooling alternatives – Lithium Bromide- Water absorption System – Aqua-ammonia absorption system – Intermittent absorption refrigeration System - Refrigerant storage for solar absorption cooling systems.

UNIT – IV COMPONENT DESIGN VAPOUR COMPRESSION REFRIGERATION 9

Vapour compression refrigeration cycles - Rankine cycle - Sterling cycle based solar cooling systems - Thermal modelling for continuous and intermittent solar refrigeration and air-conditioning systems.

UNIT – V IMPLEMENTATION TECHNIQUES 9

PV powered refrigerator – Free cooling - Solar thermoelectric refrigeration and air-conditioning – Solar economics of cooling systems - Case studies.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

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

1. Analyze the performance of different refrigeration cycles.
2. Design the different types of solar collectors for a given cooling load.
3. Analyze the performance of absorption chillers.
4. Design the solar powered vapor compression refrigeration system.
5. To analyze the economics of solar based cooling system.

REFERENCES:

1. Alefeld G. and Radermacher R., Heat Conversion Systems, CRC Press, 2004.
2. ASHRAE Hand Book–HVAC Systems & Equipment, ASHRAE Inc. Atlanta, 2008.
3. McVeigh J.C. and Sayigh A.A.M. Solar Air Conditioning and Refrigeration, Pergamon Press,1992.
4. Rakosh Das Begamudre, Energy Conversion Systems, New Age International, 2007.
5. Reinhard Radermacher, S AKelin and K Herold, Absorption chillers and heat pumps, CRC Press, 1996.
6. Tom P. Hough, Solar Energy: New Research, Nova Publishers, 2006.

PO & PSO Mapping:

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.9		0.3				0.6						0.6		
2	0.9	0.6				0.3	0.3							0.6	
3	0.9	0.6		0.3		0.3							0.3	0.6	0.9
4	0.9	0.6		0.3									0.6		0.9
5	0.9	0.6	0.6								0.6		0.6	0.6	

SY5002 SOLAR SYSTEMS FOR BUILDING TECHNIQUES L T P C

3 0 0 3

OBJECTIVES:

1. To explain the concept of solar thermal and electrical applications of building
2. To study the green buildings concepts applicable to modern and alternative building design
3. To be familiar with simple terminologies associated to building techniques
4. To know the methods to evaluate the performance of buildings
5. To summarize life cycle analysis for thermal and electrical solar systems

UNIT – I INTRODUCTION 9

Elements of Buildings - Traditional, Modern and Alternative Buildings - Concepts and Elements of Thermal Comfort - Materials and Methods of Construction - Thermal Properties of Building Elements.

UNIT – II SOLAR HEAT GAIN IN BUILDINGS 9

Building orientations - Geometric Shapes / Factors - Building Thermal Resistance - Computation of R and U Values for Building Elements and their comparison - Calculation of Solar Heat incident on various building surfaces - Diurnal and Seasonal Variation - Solar Space Conditioning.

UNIT – III SOLAR THERMAL SYSTEMS FOR BUILDINGS 9

Intuitive and responsive building design - Solar Collectors, Cookers, Thermal Energy Storage Systems and their Integration with Buildings – Advantages and Limitations - Sizing, Area and Performance Calculations.

UNIT – IV SOLAR PV SYSTEMS FOR BUILDINGS 9

Solar PV Systems for stand-alone and Grid Interconnected Applications - Integration of SPV components with buildings. Sizing, Area and Performance Calculations.

UNIT – V ECONOMIC ANALYSIS 9

Economic analysis for alternative selection of materials - Life Cycle Analysis for Thermal and Electrical Solar Systems.

TOTAL: 45 PERIODS

OUTCOMES:

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

1. Will be aware with climate responsive building design and simple concepts
2. Will Know the basic terminologies associated with buildings
3. Will be able to estimate the performance of buildings
4. Gets familiar with Renewable energy systems in buildings
5. Will understand the solar PV systems for buildings

REFERENCES:

1. David A. Bainbridge, Ken Haggard, Kenneth L. Haggard,Passive Solar Architecture: Heating, Cooling, Ventilation,Daylighting, and More Using Natural Flows, Chelsea Green Publishing, 2011.
2. John Schaeffer, Doug Pratt, Douglas R. Pratt, Solar living sourcebook, 2007.
3. Jan F. Kreider, The solar heating design process:active and passive systems, McGraw-Hill, 2007.
4. Sukhatme and Nayak , Solar Energy: Principles Of Thermal Collection & Storage, Tata McGraw- Hill, 2008
5. Ibrahim Dincer and Marc A Rosan, Thermal Energy Storage: Systems & Applications, John Wiley, 2006.

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.3	0.3	0.3	0.3	0.3	0.3		0.3				0.3	0.3		
2	0.9	0.9	0.9	0.3	0.9							0.3	0.3	0.9	0.9
3	0.9	0.9	0.9	0.9	0.9		0.9					0.3	0.3	0.9	0.9
4	0.6	0.6	0.9	0.9	0.9							0.3	0.3	0.6	
5	0.9	0.9	0.6	0.6	0.3		0.9						0.3		0.9

EY5075	ENERGY FORECASTING, MODELING AND PROJECT MANAGEMENT	L	T	P	C
		3	0	0	3

OBJECTIVES:

1. To understand about National energy scenario.
2. To predict the energy demand using various forecasting models.
3. To develop an optimization model for the effective utilisation of energy sources.
4. To know the procedure to the write the project proposal.
5. To know the energy policies in the country.

UNIT – I ENERGY SCENARIO 9

Role of energy in economic development and social transformation: Energy & GDP, GNP and its dynamics - Energy Sources and Overall Energy demand and Availability - Energy Consumption in various sectors and its changing pattern -Status of Nuclear and Renewable Energy: Present Status and future promise.

UNIT – II FORECASTING MODEL 9

Forecasting Techniques - Regression Analysis - Double Moving Average - Double Experimental Smoothing - Triple Exponential Smoothing – ARIMA model- Validation techniques – Qualitative forecasting – Delphi technique - Concept of Neural Net Works.

UNIT – III OPTIMIZATION MODEL 9

Principles of Optimization - Formulation of Objective Function - Constraints - Multi Objective Optimization – Mathematical Optimization Software – Development of Energy Optimization Model - Development of Scenarios – Sensitivity Analysis - 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 - Project Financing – Financial Evaluation.

UNIT – V ENERGY POLICY 9

National & State Level Energy Issues - National & State Energy Policy - Energy Security - National solar mission - state solar energy policy - Framework of Central Electricity Authority (CEA), Central & States Electricity Regulatory Commissions (CERC & ERCs)**-**Costing.

TOTAL: 45 PERIODS

OUTCOMES:

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

1. Have knowledge in the National energy scenario.
2. Do Energy prediction using various forecasting techniques.
3. Develop optimization model for energy planning.
4. Capable of writing project proposals.
5. Understand the National and state energy policies.

REFERENCES:

1. Armstrong J.Scott (ed.), Principles of forecasting: a hand book for researchers and practitioners, Norwell, Massachusetts: Kluwer Academic Publishers.2001.
2. DhandapaniAlagiri, Energy Security in India Current Scenario, The ICFAI University Press, 2006.
3. Fred Luthans, Brett C. Luthan, Kyle W. Luthans, Organisational Behaviour: An Evidence-Based Approach, Information Age Publishing; 13 edition, 2015
4. Spyros G. Makridakis, Steven C. Wheelwright, Rob J. Hyndman, Forecasting: Methods and Applications, 4th Edition, ISBN: 978-0-471-53233-0,2003
5. Yang X.S., Introduction to mathematical optimization: From linear programming to Metaheuristics, Cambridge, Int. Science Publishing, 2008.

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.3	0.3	0.6	0.3	0.3	0.3	0.9	0.3	0.3	0.6	0.3	0.9	0.9	0.6	0.3
2	0.9	0.6	0.9	0.9	0.9	0.6	0.6				0.3	0.6	0.9	0.6	0.6
3	0.6	0.9	0.9	0.9	0.9			0.6			0.3	0.3	0.6	0.6	0.9
4	0.6	0.3	0.3	0.6		0.6		0.6	0.6	0.9	0.9	0.6	0.6	0.9	0.6
5	0.3	0.3				0.6	0.9	0.6	0.6	0.9	0.9	0.6	0.6	0.9	0.3

EY5081 SOLAR ENERGY TECHNOLOGIES L T P C
3 0 0 3

OBJECTIVES:

1. To learn and study the solar radiation and various solar collectors
2. To study the various solar thermal energy technologies and their applications
3. To learn about various solar PV cell materials and conversion techniques
4. To learn various Solar SPV systems designs and their applications
5. To know about various solar passive building techniques for cooling and heating applications

UNIT – I SOLAR RADIATION AND COLLECTORS 9

Solar angles – Sun path diagrams – Radiation - extraterrestrial characteristics - measurement and estimation on horizontal and tilted surfaces - flat plate collector thermal analysis - testing methods- evacuated tubular collectors - concentrator collectors – classification - design and performance parameters - tracking systems - compound parabolic concentrators - parabolic trough concentrators - concentrators with point focus - Heliostats – performance of the collectors

UNIT – II SOLAR THERMAL TECHNOLOGIES 9

Principle of working, types, design and operation of - Solar heating and cooling systems - Thermal Energy storage systems – Solar Desalination – Solar cooker : domestic, community – Solar pond – Solar drying-solar chimney-solar thermal electricity conversion

UNIT – III SOLAR PV FUNDAMENTALS 9

Semiconductor – properties - energy levels - basic equations of semiconductor devices physics. Solar cells - p-n junction: homo and hetro junctions - metal-semiconductor interface - dark and illumination characteristics - figure of merits of solar cell - efficiency limits - variation of efficiency with band-gap and temperature - efficiency measurements - high efficiency cells – Solar thermo-photovoltaics

UNIT – IV SPV SYSTEM DESIGN AND APPLICATIONS 9

Solar cell array system analysis and performance prediction- Shadow analysis: reliability - solar cell array design concepts - PV system design - design process and optimization - detailed array design - storage autonomy - voltage regulation - maximum tracking - centralized and decentralized SPV systems - standalone - hybrid and grid connected system - System installation - operation and maintenances - field experience - PV market analysis and economics of SPV systems

UNIT – V SOLAR PASSIVE ARCHITECTURE 9

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

TOTAL: 45 PERIODS

OUTCOMES:

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

1. Learn and study the solar radiation and various solar collectors
2. Know the various solar thermal energy technologies and their applications
3. Aware about various solar PV cell materials and conversion techniques
4. Learn various Solar SPV systems designs and their applications
5. Know about various solar passive building techniques for cooling and heating applications

REFERENCES:

1. Chetan Singh Solanki, Solar Photovoltatics – Fundamentals, Technologies and Applications, PHI Learning Private limited, 2011
2. John A. Duffie, William A. Beckman, Solar Engineering of Thermal Processes, John Wiley & Sons, 2013
3. Lovegrove K., Stein W., Concentrating Solar Power Technology, Woodhead Publishing Series in Energy, Elsevier, 1st Edition, 2012
4. Solar Energy International, Photovoltaic – Design and Installation Manual, New Society Publishers, 2006
5. Sukhatme S P, Nayak J K, Solar Energy – Principle of Thermal Storage and collection, Tata McGraw Hill, 2008.

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.9	0.6	0.3		0.3		0.9	0.6				0.9	0.6	0.3	
2	0.9	0.6	0.6		0.6	0.3	0.9	0.6				0.9			0.6
3	0.9	0.6	0.3		0.6		0.9	0.6				0.9		0.3	
4	0.9	0.9	0.6			0.6	0.9	0.6				0.9	0.3		0.6
5	0.6	0.3	0.9		0.6	0.6	0.9	0.9				0.9	0.3	0.3	0.6

SY5003 SOLAR ENERGY APPLIANCES

L	T	P	C
3	0	0	3

OBJECTIVES:

1. To learn the principle behind operation of solar PV cell and its application in lighting system.
2. To understand the principle of working of solar cooker with types and its solar applications.
3. To learn the need for solar drying and operation of different dryer types.
4. To learn about various desalination techniques and factors influencing productivity of solar still with its types.
5. To know about solar furnaces and its components.

UNIT – I SOLAR LIGHTING 9

Solar cell – Working principle of a solar cell – Solar home lighting systems – Solar street lighting systems - Solar lanterns – Applications - Rural electrification process – Case studies.

UNIT – II SOLAR COOKING 9

Introduction – Types of solar cookers – Advantages and disadvantages - Box type – Parabolic dish cooker - Performance evaluation of solar cookers – Testing of a solar cooker – Applications of solar cooking - Case studies.

UNIT – III SOLAR DRYING 9

Introduction – Need for solar drying - Basics of solar drying – Types of solar dryers – Direct type solar dryer – Mixed mode type solar dryer – Forced circulation type dryers – Hybrid dryer – Bin type dryer – Solar timber drying – Applications - Case studies.

UNIT – IV SOLAR DESALINATION 9

Introduction – Necessity for desalination – Study on various desalination techniques – Comparison between conventional and solar desalination – Basics of solar still - Simple solar still – Material problems in solar still – Solar disinfection and its methods – Case studies on various desalination techniques.

UNIT – V SOLAR FURNACES 9

Introduction – Types of solar furnaces – Components of solar furnaces – Concentrator – Heliostat – Sun tracking – Typical solar furnace designs – Single concentrator furnace – Single heliostat solar furnace - Multiple heliostats solar furnace - Case studies on solar furnaces.

TOTAL: 45 PERIODS

OUTCOMES:

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

1. Diagnose the fundamental concepts about solar energy systems and devices.
2. Will be familiar with concepts of solar home lighting and solar street lighting systems.
3. Identify the solar cooker technologies for suitable applications.
4. Recognize the applications and types of solar dryers.
5. Aware about various desalination techniques and material problems in solar still.

REFERENCES:

1. Suhatme and Nayak, Solar Energy: Principles of Thermal Collection and Storage, Tata McGraw Hill, 2008.
2. HP Garg and J Prakash: Solar Energy: Fundamentals and Applications, Tata McGraw Hill, 2010.
3. Rai, G.D., Solar Energy Utilization, Khanna Publishers, Delhi, 2010.
4. Michael Grupp, Time to Shine: Applications of Solar Energy Technology, John Wiley & Sons, 2012.
5. SM Sze, Kwok K Ng: Physics of semiconductor devices, third edition, John Wiley & Sons, 2007.

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.9	0.6	0.3	0.3											
2	0.9	0.3	0.3	0.3											
3	0.9	0.3	0.6	0.3											
4	0.9	0.3	0.6	0.3											
5	0.9	0.3	0.3	0.3											

EY5071 ADVANCED ENERGY STORAGE TECHNOLOGIES

L	T	P	C
3	0	0	3

COURSE OBJECTIVES:

1. To understand the various types of energy storage technologies and its applications.
2. To study the various modelling techniques of energy storage systems using TRNSYS.
3. To learn the concepts and types of batteries.
4. To make the students to get understand the concepts of Hydrogen and Biogas storage.
5. To provide the insights on Flywheel and compressed energy storage systems.

UNIT – I INTRODUCTION 9

Necessity of energy storage – types of energy storage – comparison of energy storage technologies – Applications.

UNIT – II THERMAL STORAGE SYSTEM 9

Thermal storage – Types – Modelling of thermal storage units – Simple water and rock bed storage system – pressurized water storage system – Modelling of phase change storage system – Simple units, packed bed storage units - Modelling using porous medium approach, Use of TRNSYS.

UNIT – III ELECTRICAL ENERGY STORAGE 9

Fundamental concept of batteries – measuring of battery performance, charging and discharging of a battery, storage density, energy density, and safety issues. Types of batteries – Lead Acid, Nickel – Cadmium, Zinc Manganese dioxide and modern batteries for example (i) zinc-Air (ii) Nickel Hydride, (iii) Lithium Battery.

UNIT – IV HYDROGEN AND BIOGAS STORAGE 9

Hydrogen storage options – compressed gas – liquid hydrogen – Metal Hydrides, chemical Storage, Biogas storage - comparisons. Safety and management of hydrogen and Biogas storage - Applications.

UNIT – V ALTERNATE ENERGY STORAGE TECHNOLOGIES 9

Flywheel, Super capacitors, Principles & Methods – Applications, Compressed air Energy storage, Concept of Hybrid Storage – Applications.

TOTAL: 45 PERIODS

OUTCOMES:

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

1. Identify the energy storage technologies for suitable applications.
2. Analyze the energy storage systems using TRNSYS.
3. Recognize the concepts and types of batteries.
4. Diagnose the principle operations of Hydrogen and Biogas storage.
5. Analyze the concepts of Flywheel and compressed energy storage 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												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.9	0.3	0.9	0.3	0.3	0.6	0.9	0.3	0.3	0.3	0.6	0.3	0.9	0.6	0.6
2	0.9	0.3	0.9	0.3	0.3	0.6	0.9	0.3	0.3	0.3	0.6	0.3	0.9	0.6	0.6
3	0.9	0.3	0.9	0.3	0.3	0.6	0.9	0.3	0.3	0.3	0.6	0.3	0.9	0.6	0.6
4	0.9	0.3	0.9	0.3	0.3	0.6	0.9	0.3	0.3	0.3	0.6	0.3	0.9	0.6	0.6
5	0.9	0.3	0.9	0.3	0.3	0.6	0.9	0.3	0.3	0.3	0.6	0.3	0.9	0.6	0.6

EY5074 ENERGY EFFICIENT BUILDINGS DESIGN L T P C
3 0 0 3

OBJECTIVES:

1. To learn the green buildings concepts applicable to alternate design
2. To be familiar with basic terminologies related to buildings
3. To learn the building (air) conditioning techniques
4. To know the methods to evaluate the performance of buildings
5. To incorporate Renewable energy systems in buildings

UNIT I INTRODUCTION 9

Climate and Building, Historical perspective, Aspects of green building design – Sustainable Site, Water, Energy, Materials and IAQ, ECBC 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 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

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:

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

REFERENCES:

1. ASHRAE Handbook -2009 - Fundamentals.
2. Baruch Givoni: Climate considerations in building and Urban Design, John Wiley & Sons, 1998
3. Baruch Givoni: Passive Low Energy Cooling of Buildings by, John Wiley & Sons, 15-Jul-1994
4. JA Duffie and WA Beckman: Solar Engineering of Thermal Processes, Third Edition, John Wiley & Sons, 2006.
5. Jan F. Kreider, Peter S. Curtiss, Ari Rabl, Heating and cooling of buildings: Design for Efficiency, Revised Second Edition, CRC Press, 28-Dec-2009.

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.9	0.9	0.3	0.3	0.6	0.6	0.9	0.3	0.6	0.3			0.9	0.3	
2	0.9	0.9	0.9	0.3	0.3		0.9					0.3	0.3		
3	0.9	0.3	0.9		0.3	0.6	0.9		0.3			0.6	0.6	0.3	
4	0.9	0.9	0.9	0.6	0.6	0.6	0.9				0.6	0.6	0.3	0.3	0.9
5	0.9	0.6	0.9		0.9	0.3	0.9		0.6		0.6	0.6	0.6	0.3	0.9

SY5004 SOLAR POWER GENERATION TECHNOLOGIES AND POLICIES

L	T	P	C
3	0	0	3

OBJECTIVES:

1. To learn the fundamental concepts of solar energy power generating systems and devices.
2. To comprehend Indian governmental regulatory policy on renewable energy technology particularly on solar energy.
3. To appreciate the concepts adopted in techno-economic analysis of solar thermal power plants.
4. To know the energy policies in the country.
5. To forecast the energy demand using different forecasting models.

UNIT – I SOLAR THERMAL POWER GENERATION 9

Solar Parabolic trough - Design considerations, tracking and control systems - Thermal design of receivers - Solar parabolic dish - Design considerations, Sterling engine, Brayton cycle, tracking and control systems - Solar tower concepts - Tower design - Heliostat design - Receiver types, tracking and control systems - Performance study, site selection and land requirement for the above technologies - Techno-economic analysis of solar thermal power plants.

UNIT – II SOLAR PHOTOVOLTAIC POWER GENERATION 9

Solar PV technologies overview - Stationary and concentrated PV - Inverter and control technologies - Master slave inverter system design - Standalone systems - Grid connected systems - Hybridization, synchronization and power evacuation - Site selection and land requirements - Techno-economic analysis of solar PV power plants - Environmental considerations.

UNIT – III SOLAR ENERGY POLICY PLANNING 9

Elements in policy making in solar energy - Components of policy making - Essentials and other requirements - Pre-requirements of policy planning - Models for planning for effective policy making - Data requirements for policy plans - Monitoring and assessments of policies - Global policy pronouncement.

UNIT – IV SOLAR ENERGY REGULATIONS AND POLICY PROGRAMMES 9

Legislations guiding solar energy sector - Critical review of various programs of government – State regulations - Jawaharlal Nehru National Solar Mission (JNNSM) - JNNSM Regulations regarding grid interconnected solar energy systems – Solar Energy policy, 2012.

UNIT – V POLICY MANAGEMENT CHALLENGES 9

Challenges for planning and policies - Issues of subsidization - Entrepreneurship development and management challenges - Issues in entrepreneurship development and management challenges in renewable energy sector in India – Production – Storage - Transmission and distribution - End-use - Pricing, etc

TOTAL: 45 PERIODS

OUTCOMES:

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

1. The fundamentals of solar energy power generating systems and devices were learnt.
2. The Indian governmental policies on renewable energy and the policy management challenges particularly on solar energy technology were studied in detail.
3. Know the Indian and global energy scenario.
4. Learn the various solar power generation and environmental considerations.
5. Do Energy prediction using various forecasting techniques

REFERENCES:

1. Stefan C. W. Krauter, Solar Electric Power Generation - Photovoltaic Energy Systems: Modeling of optical and thermal performance, electrical yield, energy balance, effect on reduction of greenhouse gas emissions, Springer, 2006.
2. JA Duffie and WA Beckman: Solar Engineering of Thermal Processes, Third Edition, John Wiley & Sons, 2006.
3. Jayarama Reddy, Solar Power Generation: Technology, New Concepts & Policy, CRC Press, 2012.
4. VVN Kishore, Renewable Energy Engineering and Technology – A Knowledge Compendium TERI Press, 2008.
5. CS Solanki: Solar Photovoltaics – Fundamentals, Technologies and Applications, PHI Learning Pvt. Ltd., 2011.

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.9	0.3	0.6	0.3											
2	0.9	0.3	0.9				0.3								
3		0.6		0.3											
4		0.3													
5				0.3	0.3										

EY5073 ELECTRICAL DRIVES AND CONTROLS L T P C
3 0 0 3

OBJECTIVES

1. To impart the knowledge on the principle of conventional motor drives, various starting and speed control methods of motors.
2. To understand the concepts of various losses and harmonics effects in motors.
3. To study the Power Electronics components and controllers.
4. To provide insights of Superconductivity theory and super conducting magnetic energy storage.
5. To understand the concept of Solid State motor controllers and their applications

UNIT I CONVENTIONAL MOTOR DRIVES 9

Characteristics of DC and AC motor for various applications - starting and speed control - methods of breaking

UNIT II PHYSICAL PHENOMENA IN ELECTRICAL MACHINES 9

Various losses in motors-Saturation and Eddy current effects - MMF harmonics and their influence of leakage-stray losses - vibration and noise.

UNIT III SOLID STATE POWER CONTROLLERS 9

Power devices: Triggering Circuits, Rectifiers – Single Phase and Three Phase with R, RL and Freewheeling Diode, Choppers - Type-A, Type-B, Type C and Type D, Inverters - Single Phase and Three Phase with R, RL and Freewheeling Diode, AC Voltage Controllers

UNIT IV SUPERCONDUCTIVITY 9

Principle of Super conductivity, Super conducting generators-motors and magnets - Super conducting magnetic energy storage (SMES).

UNIT V SOLID STATE MOTOR CONTROLLERS 9

Single and Three Phase fed DC motor drives - AC motor drives - Voltage Control - Rotor resistance control - Frequency control - Slip Power Recovery scheme

TOTAL: 45 PERIODS

OUTCOMES

1. Diagnose the operations of conventional motor drives, various starting and speed control methods of motors.
2. Analyze the different losses and harmonic effects in motors.
3. Recognize the Power electronics components and design the controllers.
4. Apply the Superconductivity theory and analyze the super conducting magnetic energy storage.
5. Analyse the concept of Solid State motor controllers and their applications

REFERENCES

1. Subrahmanyam, Electric Drives : Concepts & Applications 2/E, Tata McGraw Hill Education,2011
2. Robert A. Huggins, Energy Storage , Springer(2010)
3. Rene Husson, Modelling and Control of Electrical machines, Elsevier Science Ltd, 2009
4. D.Singh, K.B.Khanchandani, Power Electronics, Tata McGraw Hill Education Ltd, s2006
5. Austin Hughes, Electric Motor & Drives, Newnes, 2006.

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.9	0.6	0.3	0.3		0.3							0.6	0.3	0.3
2	0.9	0.6	0.3	0.3		0.3							0.6	0.3	0.3
3	0.9	0.6	0.9	0.6		0.9							0.6	0.3	0.6
4	0.9	0.3	0.3	0.3		0.3							0.6	0.3	0.6
5	0.9	0.3	0.3	0.3		0.3							0.3	0.6	0.3

EY5079 POWER ELECTRONICS FOR RENEWABLE ENERGY SYSTEMS L T P C

3 0 0 3

OBJECTIVES:

1. To impart knowledge on conversion techniques and renewable energy technologies.
2. To study the mechanisms of machines for the conversion of renewable energy sources.
3. To learn the power converters and its applications in renewable energy systems.
4. To understand the different conversion mechanisms of wind and solar systems.
5. To understand the various hybrid systems of renewable energy conversion techniques.

UNIT I INTRODUCTION 9

Environmental aspects of electric energy conversion: impacts of renewable energy generation on environment (cost-GHG Emission) - Qualitative study of different renewable energy resources: Solar, wind, ocean, Biomass, Fuel cell, Hydrogen energy systems and hybrid renewable energy systems

UNIT II ELECTRICAL MACHINES FOR RENEWABLE ENERGY CONVERSION 9

Review of reference theory fundamentals-principle of operation and analysis: IG, PMSG, SCIG and DFIG

UNIT III POWER CONVERTERS 9

Solar: Block diagram of solar photo voltaic system -Principle of operation: line commutated converters (inversion-mode) - Boost and buck-boost converters- selection of inverter, battery sizing, array sizing Wind: three phase AC voltage controllers- AC-DC-AC converters: uncontrolled rectifiers, PWM Inverters, Grid Interactive Inverters-matrix converters. Power Quality Measurements.

UNIT IV ANALYSIS OF WIND AND PV SYSTEMS 9

Stand-alone operation of fixed and variable speed wind energy conversion systems and solar system- Grid connection Issues -Grid integrated PMSG and SCIG Based WECS Grid Integrated solar system

UNIT V HYBRID RENEWABLE ENERGY SYSTEMS 9

Need for Hybrid Systems- Range and type of Hybrid systems- Case studies of Wind-PV Maximum Power Point Tracking (MPPT).

TOTAL: 45 PERIODS

OUTCOMES:

1. Analyze the various conversion techniques in renewable energy technologies.
2. Apply the various mechanisms for the conversion of renewable energy sources.
3. Identify the appropriate power converters for renewable energy systems.
4. Implement the different conversion mechanisms for wind and solar systems.
5. Recognize the importance of various hybrid renewable energy systems.

REFERENCES

1. Leon Freris, David Infield, “Renewable energy in power systems”, John Wiley & Sons, 2008.
2. Rashid .M. H “power electronics Hand book”, Academic press, 2007.
3. Rai. G.D, “Non-conventional energy sources”, Khanna publishes, 2010.
4. Ali Keyhani, Design of Smart Power Grid Renewable Energy Systems, John Wiley & Sons, 2011.
5. Wind Electric Systems: S.N. Bhadra, D. Kastha, OXFORD university press, 2005.

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.9	0.9	0.3	0.3	0.6	0.3	0.6	-	-	-	-	0.3	0.6	0.3	0.3
2	0.6	0.9	0.3	0.3	0.6	0.3	0.6	-	-	-	-	0.3	0.6	0.3	0.3
3	0.9	0.9	0.9	0.6	0.9	0.3	0.9	-	-	-	-	0.3	0.6	0.3	0.3
4	0.3	0.6	0.3	0.3	0.6	0.3	0.6	-	-	-	-	-	0.6	0.3	0.3
5	0.3	0.3	0.3	0.3	-	0.3	0.3	-	-	-	-	-	0.3	0.6	0.3

SY5005	SOLAR POWER PLANTS	L	T	P	C
		3	0	0	3

OBJECTIVES:

1. To explain concept of various power cycles involved in the solar power plants
2. To learn and study the solar radiation and various solar power plants
3. To outline the variety of solar systems used to collect solar energy
4. To learn electrical performance of PV power plants.
5. To summarize basic economics of solar power plants.

UNIT – I INTRODUCTION 9

Power Plant Scenario - Classification, Basic Principles and Features - Comparison and selection Criteria.

UNIT – II SOLAR POWER CYCLES 9

"Vapour cycles – Organic cycles – Combined Cycles – Binary Cycles – Stirling Cycle – Brayton Cycle – Ericsson Cycle – Kalina Cycle."

UNIT – III SOLAR THERMAL POWER PLANTS 9

Collector, Receiver, Energy Transfer Power cycles - Tower, Trough and Dish Systems - Concentrating Dish Systems - Concentrating Linear Fresnel Reflectors - Combined and Binary Cycles - Solar Chimneys - Hybrid Systems.

UNIT – IV SOLAR PV POWER PLANTS 9

International PV Power Programmes - Photovoltaic Power Systems - System Integration - Energy Storage - Power Electronics - Stand-Alone Systems - Grid-Connected Systems - Concentrating Photovoltaics (CPV) - Electrical Performance.

UNIT – V ECONOMICS OF POWER PLANTS 9

Methods of fixing power tariff - Simple Methods to Calculate the Plant Economy - Life Cycle Cost - Payback Period - Economic Analysis for the Selection of Alternative Decisions and the future of the Power Plants.

TOTAL: 45 PERIODS

OUTCOMES:

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

1. The concept of various power cycles involved in the solar power plants were learnt.
2. Learn and study the solar radiation and various solar collectors
3. Know the various solar thermal energy technologies and their applications
4. The variety of solar systems used to collect solar energy were studied in detail.
5. The basic economics of solar power plants were understood

REFERENCES:

1. Duffie, J.A., and Beckman, W.A. Solar Energy Thermal Process, John Wiley and Sons, New York, 2006.
2. Kosuke Kurokawa (Ed.), Eergy from the Desert – Feasibility of very large-scale photovoltaic power generation systems, James and James 2003.
3. Sukhatme S.P., Solar Energy, Tata McGraw Hills P Co., 3rd Edition, 2008.
4. C.J. Winter, R.L. Sizmann, L.L. Vant-Hull, Solar Power Plants, Springer- Verlag Berlin and Heidelberg GmbH & Co. K, 2001.
5. Tomas Markvart, Solar electricity, John Wiley & Sons, 2003.

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.3						0.6								
2	0.3						0.6								
3			0.3				0.6								
4			0.3				0.6								
5		0.6					0.6				0.6				

SY5006	SOLAR PASSIVE ARCHITECTURE	L	T	P	C
		3	0	0	3

OBJECTIVES:

1. To learn the fundamental concepts of solar passive building architecture
2. To know the concepts of passive solar heating and cooling of buildings.
3. To learn about various building materials.
4. To know the zero energy building concept and rating systems
5. To study the energy management of buildings and green globe assessment standards.

UNIT – I INTRODUCTION 9

Need for passive architecture - Building form and functions – General aspects of solar passive heating and cooling of buildings – Thumb rules - Thermal comfort – Sun's motion – Building orientation and design – Heat transfer in buildings.

UNIT – II PASSIVE SOLAR HEATING OF BUILDINGS 9

Direct gain – Indirect gain – Isolated gain - Passive heating concept - Thermal modeling of passive concepts – Thermal storage wall and roof – Sunspace – Prediction of heating loads in a building.

UNIT – III PASSIVE COOLING OF BUILDINGS 9

Passive cooling concept - Solarium Passive cooling - Ventilation cooling - Nocturnal radiation cooling - Evaporative cooling - Roof surface evaporative cooling (RSEC) - Direct evaporative cooling using drip-type (desert) coolers – Radiation cooling - Earth coupling - Basic principles and systems.

UNIT – IV CLIMATE AND HUMAN THERMAL COMFORT 9

Factors affecting climate - Climatic zones and their characteristics - Urban climate - Microclimate - Implications of climate on building design - Principles of energy conscious design - Building materials - Embodied energy of building materials - Alternative building materials.

UNIT – V BUILDING RATING SYSTEMS 9

Zero energy building concept and rating systems - Energy conservation building codes – Energy management of buildings – Green globe assessment Standards –BREEAM – CASBEE – Green star– Review of CDM Techniques - GRIHA and others.

TOTAL: 45 PERIODS

OUTCOMES:

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

1. The fundamental concepts of solar passive architecture were understood along with examples and case studies.
2. The concepts of passive solar heating and cooling of buildings, human comfort conditions.
3. Aware about various building materials.
4. Know the zero energy building concept and rating systems.
5. Learn the energy management of buildings and green globe assessment standards.

REFERENCES:

1. Jan F. Kreider, The solar heating design process: active and passive systems, McGraw-Hill, 2007.
2. David A. Bainbridge, Ken Haggard, Kenneth L. Haggard, Passive Solar Architecture: Heating, Cooling, Ventilation, Daylighting, and More Using Natural Flows, Chelsea Green Publishing, 2011.
3. VVN Kishore, Renewable Energy Engineering and Technology – A Knowledge Compendium, TERI Press, 2008.
4. HP Garg and J Prakash: Solar Energy: Fundamentals and Applications, Tata McGraw Hill, 2010.
5. S Sukhatme and J Nayak: Solar Energy: Principles of Thermal Collection and Storage, Third Edition, Tata McGraw Hill, 2008.

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.3	0.3	0.3	0.3	0.3	0.3		0.3				0.3	0.3		
2	0.9	0.9	0.9	0.3	0.9							0.3	0.3	0.9	0.9
3	0.9	0.9	0.9	0.9	0.9		0.9					0.3	0.3	0.9	0.9
4	0.6	0.6	0.9	0.9	0.9							0.3	0.3	0.9	
5	0.9	0.9	0.6	0.6	0.3		0.9						0.3	0.6	0.9

EY5076 **ENVIRONMENTAL ENGINEERING AND POLLUTION CONTROL** **L T P C**
3 0 0 3

OBJECTIVES:

1. To impart knowledge on the atmosphere and its present condition and, global warming.
2. To detail on the sources of water pollution and possible solutions for mitigating their degradation.
3. To detail on the sources of air pollution and possible solutions for mitigating their degradation.
4. To detail on the sources of solid waste and possible ways to dispose them safely.
5. To impart knowledge on hazardous waste management.

UNIT – I INTRODUCTION **9**

Man & Environment – Types of Pollution – Global Environmental issues – Environmental Impact Assessment – Global Warming Issues – CO_2 Mitigation – Basic definition of Pollution Indicators – Noise Pollution

UNIT – II WATER POLLUTION **9**

Pollutants in Water & Wastewater – Physical and Chemical Treatment Methods – (An Overview) Neutralization – Aeration –Colour / Odour Removal - Sludge dewatering – Biological Treatment including Aerobic & Anaerobic Treatment

UNIT – III AIR POLLUTION **9**

Sources – Ambient Air Quality Standards – Emission Limits – Equipment for Ambient Air & Stack Monitoring – Principles of operation of Particulate Control Equipments -ESPs, Bag Filters, Cyclone Separators– Vehicular Pollution and its Control – BS standards

UNIT – IV SOLID WASTE MANAGEMENT **9**

Types & Sources – Types– Waste Generation – Composition – Physical, Chemical and Biological Properties – Transformation Technologies for Waste Treatment – Landfill Management – Layout, Closure & Post Closure Operation – Reclamation Leachate Generation – e Waste Disposal

UNIT – V HAZARDOUS WASTE MANAGEMENT **9**

Sources – Classification – Characterization of waste - health effects - Incineration– Radioactive Waste from nuclear power plants and disposal options - RDF- Mass Firing – Material Recycling

TOTAL: 45 PERIODS

OUTCOMES:

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

1. Types and effects of each type of pollution on man – earth will be made known.
2. Technical aspects of Global Warming will make them understand the impact they have on climate
3. Technologies that are available for reduction of pollutants dumped into the atmosphere

4. Cursory / superficial formation - the students – had in Hazardous waste, waste disposal hitherto will be deep & sensible enough after studying this subject
5. Comprehend the different techniques available for safe disposal of hazardous waste

REFERENCES:

1. Peavy, H.S. and D.R. Rowe, G.Tchobanoglous: Environmental Engineering - McGraw- Hill Book Company, NewYork, 1985.
2. Ludwig, H. W.Evans: Manual of Environmental Technology in Developing Countries, International Book Company, Absecon Highlands, N.J, 1991.
3. Arcadio P Sincero and G. A. Sincero, Environmental Engineering – A Design Approach, Prentice Hall of India Pvt Ltd, New Delhi, 2002.
4. G. Masters: Introduction to Environmental Engineering and Science, Prentice Hall of India Pvt Ltd, New Delhi, 2003.
5. Richard J. Watts, Hazardous Wastes - Sources, Pathways, Receptors John Wiley and Sons, New York,1997

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.6	0.3	0.3	0.3	0.3	0.3	0.3						0.3		
2	0.6	0.3	0.3	0.3	0.3		0.3						0.3		0.3
3	0.9	0.3	0.6	0.3	0.3		0.6						0.3	0.9	0.3
4	0.6	0.3	0.3	0.3	0.3		0.6						0.3	0.3	0.3
5	0.3	0.3	0.6	0.6	0.9										0.9

EY5080 SMART GRIDS L T P C
3 0 0 3

OBJECTIVES

1. To Study about Smart Grid technologies with its benefits and challenges
2. To study about smart grid transmission technologies
3. To study about smart grid distribution technologies
4. To familiarize about smart metering and need for Advanced metering infrastructure
5. To familiarize the high performance computing for Smart Grid applications

UNIT I INTRODUCTION TO SMART GRID 9

Evolution of Electric Grid, Concept, Definitions and Need for Smart Grid, Smart grid drivers, functions, opportunities, challenges and benefits, Difference between conventional & Smart Grid, National and International Initiatives in Smart Grid.

UNIT II SMART GRID TECHNOLOGIES (Transmission) 9

Technology Drivers, Smart energy resources, Smart substations, Substation Automation, Feeder Automation, Transmission systems: EMS, FACTS and HVDC, Wide area monitoring, Protection and control.

UNIT III SMART GRID TECHNOLOGIES (Distribution) 9

DMS, Volt/VArcontrol, Fault Detection, Isolation and service restoration, Outage management, High-Efficiency Distribution Transformers, Phase Shifting Transformers, Plug in Hybrid Electric Vehicles (PHEV).

UNIT IV SMART METERS AND ADVANCED METERING INFRASTRUCTURE 9

Introduction to Smart Meters, Advanced Metering infrastructure (AMI) drivers and benefits, AMI protocols, standards and initiatives, AMI needs in the smart grid, Phasor Measurement Unit (PMU), Intelligent Electronic Devices(IED) & their application for monitoring & protection.

UNIT V HIGH PERFORMANCE COMPUTING FOR SMART GRID APPLICATIONS 9

Local Area Network (LAN), House Area Network (HAN), Wide Area Network (WAN), Broadband over Power line (BPL), IP based Protocols, Basics of Web Service and CLOUD Computing to make Smart Grids smarter, Cyber Security for Smart Grid.

TOTAL: 45 PERIODS

OUTCOMES

1. Students will develop more understanding on the concepts of Smart Grid and its present developments.
2. Students will study about different Smart Grid technologies.
3. Students will acquire knowledge about different smart meters and advanced metering infrastructure.
4. Students will have knowledge on power quality management in Smart Grids
5. Students will develop more understanding on LAN, WAN and Cloud Computing for Smart Grid applications.

REFERENCES:

1. Vehbi C. Güngör, Dilan Sahin, Taskin Kocak, Salih Ergüt, Concettina Buccella, Carlo Cecati, and Gerhard P. Hancke, Smart Grid Technologies: Communication Technologies and Standards IEEE Transactions On Industrial Informatics, Vol. 7, No. 4, November 2011.
2. Xi Fang, Satyajayant Misra, Guoliang Xue, and Dejun Yang "Smart Grid – The New and Improved Power Grid: A Survey" , IEEE Transaction on Smart Grids.
3. Stuart Borlase "Smart Grid : Infrastructure, Technology and Solutions",CRC Press, 2012.
4. Janaka Ekanayake, Nick Jenkins, Kithsiri Liyanage, Jianzhong Wu, Akihiko Yokoyama, "Smart Grid: Technology and Applications", Wiley, 2012
5. Fabio Toledo "Smart Metering Handbook", PennWell Corporation, 2013.

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.6	0.3	0.3	0.3	0.3	0.3	0.3						0.3		
2	0.6	0.3	0.3	0.3	0.3		0.3						0.3		0.3
3	0.9	0.3	0.6	0.3	0.3		0.6						0.3	0.9	0.3
4	0.6	0.3	0.3	0.3	0.3		0.6						0.3	0.3	0.3
5	0.3	0.3	0.6	0.6	0.9										0.9

SY5007 SOLAR ENERGY FOR INDUSTRIAL PROCESS HEATING

L	T	P	C
3	0	0	3

OBJECTIVES:

1. To learn the basic concepts of solar energy related industrial process heat.
2. To familiarize about materials for flat plate collector and their properties.
3. To study about industrial hot water, hot sir and steam process heat system.
4. To understand the applications of solar industrial process heat.
5. To study the techno-economic details for the related process heat industries.

UNIT – I INTRODUCTION **9**

Solar energy – Availability and utilization - Historical background of solar industrial process heat (IPH) - Need of the day – Opportunities and challenges of industrial process heat - Characteristics of industrial process heat.

UNIT – II SOLAR ENERGY COLLECTORS FOR INDUSTRIAL PROCESS HEATING **9**

Flat plate collector - Materials for flat plate collector and their properties– Evacuated tube collector - Solar point collector - Concentrating collectors - types and applications of concentrating collectors - Thermal Analysis of Collectors and Useful Heat Gained by the fluid - fin efficiency - collector efficiency factor - Heat Removal Factor.

UNIT – III INDUSTRIAL PROCESS HEATING SYSTEM 9

Introduction – Hot water industrial process heat system – Hot air industrial process heat system – Steam industrial process heat system – Problems involved with industrial process heat system – Case studies on industrial process heat.

UNIT – IV APPLICATIONS OF SOLAR INDUSTRIAL PROCESS HEAT 9

Industrial sectors and processes with the potential for solar thermal uses - Food and beverage industries - The textile and chemical industries - Power generation applications – Washing process – Drying process – Distillation and chemical process.

UNIT – V TECHNO-ECONOMIC ANALYSIS 9

Introduction – Heat loss calculations of thermal systems – flat plate collector – concentrating collector - Food and beverage systems – The textile and chemical process systems - Washing process – Drying process – Distillation and chemical process – Installation cost – operating cost – interest rate – payback period – sellback - Penalties for emissions or rewards for their reduction.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

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

1. The basic concepts of solar energy-related industrial process heat systems were understood.
2. Students will have knowledge on materials for flat plate collector and their properties.
3. Students will acquire knowledge about industrial hot water, hot sir and steam process heat system.
4. Learn the various applications of solar industrial process heat.
5. The techno-economic details for the related process heat industries were incorporated.

REFERENCES:

1. HP Garg and J Prakash: Solar Energy: Fundamentals and Applications, Tata McGraw Hill, 2010.
2. JA Duffie and WA Beckman, Solar Engineering of Thermal Processes, John Wiley & sons, 2006.
3. Soteris A. Kalogirou, Solar Energy Engineering: Processes and Systems, Academic Press, 2009.
4. Tom P. Hough, Solar energy: recent developments, Nova Publishers, 2007.
5. G. N. Tiwari, Solar Energy: Technology Advances, Nova Publishers, 2006.

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.9	0.6	0.3		0.6	0.6	0.9	0.6					0.6	0.3	
2	0.6	0.9	0.9		0.3		0.9	0.6				0.3			0.6
3	0.6	0.3	0.6		0.3	0.6	0.9					0.6		0.3	
4	0.6	0.9	0.9		0.6	0.6	0.9					0.6	0.3		0.6
5	0.3	0.6	0.6		0.9	0.3	0.9					0.6	0.3	0.3	0.6

OPEN ELECTIVE COURSES (OEC)

OE5091 BUSINESS DATA ANALYTICS L T P C

3 0 0 3

COURSE OBJECTIVES:

- To understand the basics of business analytics and its life cycle.
- To gain knowledge about fundamental business analytics.
- To learn modeling for uncertainty and statistical inference.
- To understand analytics using Hadoop and Map Reduce frameworks.
- To acquire insight on other analytical frameworks.

UNIT I OVERVIEW OF BUSINESS ANALYTICS 9

Introduction – Drivers for Business Analytics – Applications of Business Analytics: Marketing and Sales, Human Resource, Healthcare, Product Design, Service Design, Customer Service and Support – Skills Required for a Business Analyst – Framework for Business Analytics Life Cycle for Business Analytics Process.

Suggested Activities:

- Case studies on applications involving business analytics.
- Converting real time decision making problems into hypothesis.
- Group discussion on entrepreneurial opportunities in Business Analytics.

Suggested Evaluation Methods:

- Assignment on business scenario and business analytical life cycle process.
- Group presentation on big data applications with societal need.
- Quiz on case studies.

UNIT II ESSENTIALS OF BUSINESS ANALYTICS 9

Descriptive Statistics – Using Data – Types of Data – Data Distribution Metrics: Frequency, Mean, Median, Mode, Range, Variance, Standard Deviation, Percentile, Quartile, z-Score, Covariance, Correlation – Data Visualization: Tables, Charts, Line Charts, Bar and Column Chart, Bubble Chart, Heat Map – Data Dashboards.

Suggested Activities:

- Solve numerical problems on basic statistics.
- Explore chart wizard in MS Excel Case using sample real time data for data visualization.
- Use R tool for data visualization.

Suggested Evaluation Methods:

- Assignment on descriptive analytics using benchmark data.
- Quiz on data visualization for univariate, bivariate data.

UNIT III MODELING UNCERTAINTY AND STATISTICAL INFERENCE 9

Modeling Uncertainty: Events and Probabilities – Conditional Probability – Random Variables – Discrete Probability Distributions – Continuous Probability Distribution – Statistical Inference: Data Sampling – Selecting a Sample – Point Estimation – Sampling Distributions – Interval Estimation – Hypothesis Testing.

Suggested Activities:

- Solving numerical problems in sampling, probability, probability distributions and hypothesis testing.
- Converting real time decision making problems into hypothesis.

Suggested Evaluation Methods:

- Assignments on hypothesis testing.
- Group presentation on real time applications involving data sampling and hypothesis testing.
- Quizzes on topics like sampling and probability.

UNIT IV ANALYTICS USING HADOOP AND MAPREDUCE FRAMEWORK 9

Introducing Hadoop – RDBMS versus Hadoop – Hadoop Overview – HDFS (Hadoop Distributed File System) – Processing Data with Hadoop – Introduction to MapReduce – Features of MapReduce – Algorithms Using Map-Reduce: Matrix-Vector Multiplication, Relational Algebra Operations, Grouping and Aggregation – Extensions to MapReduce.

Suggested Activities:

- Practical – Install and configure Hadoop.
- Practical – Use web based tools to monitor Hadoop setup.
- Practical – Design and develop MapReduce tasks for word count, searching involving text corpus etc.

Suggested Evaluation Methods:

- Evaluation of the practical implementations.
- Quizzes on topics like HDFS and extensions to MapReduce.

UNIT V OTHER DATA ANALYTICAL FRAMEWORKS 9

Overview of Application development Languages for Hadoop – PigLatin – Hive – Hive Query Language (HQL) – Introduction to Pentaho, JAQL – Introduction to Apache: Sqoop, Drill and Spark, Cloudera Impala – Introduction to NoSQL Databases – Hbase and MongoDB.

Suggested Activities:

- Practical – Installation of NoSQL database like MongoDB.
- Practical – Demonstration on Sharding in MongoDB.
- Practical – Install and run Pig
- Practical – Write PigLatin scripts to sort, group, join, project, and filter data.
- Design and develop algorithms to be executed in MapReduce involving numerical methods for analytics.

Suggested Evaluation Methods:

- Mini Project (Group) – Real time data collection, saving in NoSQL, implement analytical techniques using Map-Reduce Tasks and Result Projection.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

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

- Identify the real world business problems and model with analytical solutions.
- Solve analytical problem with relevant mathematics background knowledge.
- Convert any real world decision making problem to hypothesis and apply suitable statistical testing.
- Write and Demonstrate simple applications involving analytics using Hadoop and MapReduce
- Use open source frameworks for modeling and storing data.
- Apply suitable visualization technique using R for visualizing voluminous data.

REFERENCES:

1. Vignesh Prajapati, “Big Data Analytics with R and Hadoop”, Packt Publishing, 2013.
2. Umesh R Hodeghatta, Umesha Nayak, “Business Analytics Using R – A Practical Approach”, Apress, 2017.
3. Anand Rajaraman, Jeffrey David Ullman, “Mining of Massive Datasets”, Cambridge University Press, 2012.
4. Jeffrey D. Camm, James J. Cochran, Michael J. Fry, Jeffrey W. Ohlmann, David R. Anderson, “Essentials of Business Analytics”, Cengage Learning, second Edition, 2016.
5. U. Dinesh Kumar, “Business Analytics: The Science of Data-Driven Decision Making”, Wiley, 2017.
6. A. Ohri, “R for Business Analytics”, Springer, 2012
7. Rui Miguel Forte, “Mastering Predictive Analytics with R”, Packt Publication, 2015.

OE5092 INDUSTRIAL SAFETY L T P C

3 0 0 3

COURSE OBJECTIVES:

- Summarize basics of industrial safety
- Describe fundamentals of maintenance engineering
- Explain wear and corrosion
- Illustrate fault tracing
- Identify preventive and periodic maintenance

UNIT I INTRODUCTION 9

Accident, causes, types, results and control, mechanical and electrical hazards, types, causes and preventive steps/procedure, describe salient points of factories act 1948 for health and safety,

wash rooms, drinking water layouts, light, cleanliness, fire, guarding, pressure vessels, etc, Safety color codes. Fire prevention and firefighting, equipment and methods.

UNIT II FUNDAMENTALS OF MAINTENANCE ENGINEERING 9

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

UNIT III WEAR AND CORROSION AND THEIR PREVENTION 9

Wear- types, causes, effects, wear reduction methods, lubricants-types and applications, Lubrication methods, general sketch, working and applications, i. Screw down grease cup, ii. Pressure grease gun, iii. Splash lubrication, iv. Gravity lubrication, v. Wick feed lubrication vi. Side feed lubrication, vii. Ring lubrication, Definition, principle and factors affecting the corrosion. Types of corrosion, corrosion prevention methods.

UNIT IV FAULT TRACING 9

Fault tracing-concept and importance, decision tree concept, need and applications, sequence of fault finding activities, show as decision tree, draw decision tree for problems in machine tools, hydraulic, pneumatic, automotive, thermal and electrical equipment's like, I. Any one machine tool, ii. Pump iii. Air compressor, iv. Internal combustion engine, v. Boiler, vi. Electrical motors, Types of faults in machine tools and their general causes.

UNIT V PERIODIC AND PREVENTIVE MAINTENANCE 9

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

TOTAL: 45 PERIODS

COURSE OUTCOMES:

CO1: Ability to summarize basics of industrial safety
CO2: Ability to describe fundamentals of maintenance engineering
CO3: Ability to explain wear and corrosion
CO4: Ability to illustrate fault tracing
CO5: Ability to identify preventive and periodic maintenance

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓											
CO2	✓											
CO3	✓	✓	✓									
CO4	✓	✓	✓									
CO5	✓	✓	✓									

REFERENCES:

1. Audels, Pump-hydraulic Compressors, Mcgrew Hill Publication, 1978.
2. Garg H P,Maintenance Engineering, S. Chand and Company,1987.
3. Hans F. Winterkorn ,Foundation Engineering Handbook, Chapman & Hall London,2013.
4. Higgins & Morrow , Maintenance Engineering Handbook, Eighth Edition,2008

OE5093 OPERATIONS RESEARCH L T P C

3 0 0 3

COURSE OBJECTIVES:

- Solve linear programming problem and solve using graphical method.
- Solve LPP using simplex method
- Solve transportation , assignment problems
- Solve project management problems
- Solve scheduling problems

UNIT I LINEAR PROGRAMMING 9

Introduction to Operations Research – assumptions of linear programming problems - Formulations of linear programming problem – Graphical method

UNIT II ADVANCES IN LINEAR PROGRAMMING 9

Solutions to LPP using simplex algorithm- Revised simplex method - primal dual relationships – Dual simplex algorithm - Sensitivity analysis

UNIT III NETWORK ANALYSIS – I 9

Transportation problems -Northwest corner rule, least cost method, Voges's approximation method - Assignment problem -Hungarian algorithm

UNIT IV NETWORK ANALYSIS – II 9

Shortest path problem: Dijkstra's algorithms, Floyds algorithm, systematic method -CPM/PERT

UNIT V NETWORK ANALYSIS – III 9

Scheduling and sequencing - single server and multiple server models - deterministic inventory models - Probabilistic inventory control models

TOTAL: 45 PERIODS

COURSE OUTCOMES:

CO1: To formulate linear programming problem and solve using graphical method.
CO2: To solve LPP using simplex method
CO3: To formulate and solve transportation, assignment problems
CO4: To solve project management problems
CO5: To solve scheduling problems

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓											
CO2	✓											
CO3	✓	✓	✓									
CO4	✓	✓	✓									
CO5	✓	✓	✓									

REFERENCES:

1. Harvey M Wagner, Principles of Operations Research: Prentice Hall of India 2010
2. Hitler Libermann, Operations Research: McGraw Hill Pub. 2009
3. Pant J C, Introduction to Optimisation: Operations Research, Jain Brothers, Delhi, 2008
4. Pannerselvam, Operations Research: Prentice Hall of India 2010
5. Taha H A, Operations Research, An Introduction, PHI, 2008

OE5094 COST MANAGEMENT OF ENGINEERING PROJECTS L T P C
3 0 0 3

COURSE OBJECTIVES:

- Summarize the costing concepts and their role in decision making
- Infer the project management concepts and their various aspects in selection
- Interpret costing concepts with project execution
- Develop knowledge of costing techniques in service sector and various budgetary control techniques
- Illustrate with quantitative techniques in cost management

UNIT I INTRODUCTION TO COSTING CONCEPTS 9

Objectives of a Costing System; Cost concepts in decision-making; Relevant cost, Differential cost, Incremental cost and Opportunity cost; Creation of a Database for operational control.

UNIT II INTRODUCTION TO PROJECT MANAGEMENT 9

Project: meaning, Different types, why to manage, cost overruns centres, various stages of project execution: conception to commissioning. Project execution as conglomeration of technical and nontechnical activities, Detailed Engineering activities, Pre project execution main clearances and documents, Project team: Role of each member, Importance Project site: Data required with significance, Project contracts.

UNIT III PROJECT EXECUTION AND COSTING CONCEPTS 9

Project execution Project cost control, Bar charts and Network diagram, Project commissioning: mechanical and process, Cost Behavior and Profit Planning Marginal Costing; Distinction between Marginal Costing and Absorption Costing; Break-even Analysis, Cost-Volume-Profit Analysis, Various decision-making problems, Pricing strategies: Pareto Analysis, Target costing, Life Cycle Costing.

UNIT IV COSTING OF SERVICE SECTOR AND BUDGETERY CONTROL 9

Just-in-time approach, Material Requirement Planning, Enterprise Resource Planning, Activity-Based Cost Management, Bench Marking; Balanced Score Card and Value-Chain Analysis, Budgetary Control: Flexible Budgets; Performance budgets; Zero-based budgets.

UNIT V QUANTITATIVE TECHNIQUES FOR COST MANAGEMENT 9

Linear Programming, PERT/CPM, Transportation problems, Assignment problems, Learning Curve Theory.

TOTAL: 45 PERIODS

OUTCOMES

CO1 – Understand the costing concepts and their role in decision making
CO2–Understand the project management concepts and their various aspects in selection
CO3–Interpret costing concepts with project execution
CO4–Gain knowledge of costing techniques in service sector and various budgetary control techniques
CO5 - Become familiar with quantitative techniques in cost management

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓		✓			✓	✓		✓	✓
CO2	✓	✓	✓		✓				✓		✓	✓
CO3	✓	✓	✓		✓	✓					✓	✓
CO4	✓	✓	✓		✓		✓				✓	✓
CO5	✓	✓	✓		✓	✓	✓				✓	✓

REFERENCES:

1. Ashish K. Bhattacharya, Principles & Practices of Cost Accounting A. H. Wheeler publisher, 1991
2. Charles T. Horngren and George Foster, Advanced Management Accounting, 1988

3. Charles T. Horngren et al Cost Accounting A Managerial Emphasis, Prentice Hall of India, New Delhi, 2011
4. Robert S Kaplan Anthony A. Alkinson, Management & Cost Accounting, 2003
5. Vohra N.D., Quantitative Techniques in Management, Tata McGraw Hill Book Co. Ltd, 2007

OE5095 COMPOSITE MATERIALS L T P C
3 0 0 3

COURSE OBJECTIVES:

- Summarize the characteristics of composite materials and effect of reinforcement in composite materials.
- Identify the various reinforcements used in composite materials.
- Compare the manufacturing process of metal matrix composites.
- Understand the manufacturing processes of polymer matrix composites.
- Analyze the strength of composite materials.

UNIT I INTRODUCTION 9

Definition – Classification and characteristics of Composite materials - Advantages and application of composites - Functional requirements of reinforcement and matrix - Effect of reinforcement (size, shape, distribution, volume fraction) on overall composite performance.

UNIT II REINFORCEMENTS 9

Preparation-layup, curing, properties and applications of glass fibers, carbon fibers, Kevlar fibers and Boron fibers - Properties and applications of whiskers, particle reinforcements - Mechanical Behavior of composites: Rule of mixtures, Inverse rule of mixtures - Isostrain and Isostress conditions.

UNIT III MANUFACTURING OF METAL MATRIX COMPOSITES 9

Casting – Solid State diffusion technique - Cladding – Hot isostatic pressing - Properties and applications. Manufacturing of Ceramic Matrix Composites: Liquid Metal Infiltration – Liquid phase sintering. Manufacturing of Carbon – Carbon composites: Knitting, Braiding, Weaving - Properties and applications.

UNIT IV MANUFACTURING OF POLYMER MATRIX COMPOSITES 9

Preparation of Moulding compounds and prepregs – hand layup method – Autoclave method – Filament winding method – Compression moulding – Reaction injection moulding - Properties and applications.

UNIT V STRENGTH 9

Laminar Failure Criteria-strength ratio, maximum stress criteria, maximum strain criteria, interacting failure criteria, hygrothermal failure. Laminate first play failure-insight strength; Laminate strength-ply discount truncated maximum strain criterion; strength design using caplet plots; stress concentrations.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

- CO1 - Know the characteristics of composite materials and effect of reinforcement in composite materials.
- CO2 – Know the various reinforcements used in composite materials.
- CO3 – Understand the manufacturing processes of metal matrix composites.
- CO4 – Understand the manufacturing processes of polymer matrix composites.
- CO5 – Analyze the strength of composite materials.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1		✓	✓	✓								

CO2		✓	✓	✓	✓						✓	
CO3			✓	✓	✓		✓				✓	
CO4			✓	✓	✓		✓				✓	
CO5				✓	✓		✓					

REFERENCES:

1. Cahn R.W. - Material Science and Technology – Vol 13 – Composites, VCH, West Germany.
2. Callister, W.D Jr., Adapted by Balasubramaniam R, Materials Science and Engineering, An introduction, John Wiley & Sons, NY, Indian edition, 2007.
3. Chawla K.K., Composite Materials, 2013.
4. Lubin.G, Hand Book of Composite Materials, 2013.

OE5096 WASTE TO ENERGY L T P C
3 0 0 3

COURSE OBJECTIVES:

- Interpret the various types of wastes from which energy can be generated
- Develop knowledge on biomass pyrolysis process and its applications
- Develop knowledge on various types of biomass gasifiers and their operations
- Invent knowledge on biomass combustors and its applications on generating energy
- Summarize the principles of bio-energy systems and their features

UNITI INTRODUCTION TO EXTRACTION OF ENERGY FROM WASTE 9

Classification of waste as fuel – Agro based, Forest residue, Industrial waste - MSW – Conversion devices – Incinerators, gasifiers, digestors

UNITII BIOMASS PYROLYSIS 9

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

UNIT III BIOMASS GASIFICATION 9

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

UNIT IV BIOMASS COMBUSTION 9

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

UNITV BIO ENERGY 9

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

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 on biomass combustors and its applications on generating energy

CO5 – Understand the principles of bio-energy systems and their features

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓		✓									✓
CO2	✓		✓									✓
CO3	✓	✓	✓		✓							✓
CO4	✓	✓	✓		✓		✓					✓
CO5	✓	✓	✓		✓							✓

REFERENCES:

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

AUDIT COURSES (AC)

AX5091 ENGLISH FOR RESEARCH PAPER WRITING L T P C
2 0 0 0

COURSE OBJECTIVES:

- Teach how to improve writing skills and level of readability
- Tell about what to write in each section
- Summarize the skills needed when writing a Title
- Infer the skills needed when writing the Conclusion
- Ensure the quality of paper at very first-time submission

UNIT I INTRODUCTION TO RESEARCH PAPER WRITING 6

Planning and Preparation, Word Order, Breaking up long sentences, Structuring Paragraphs and Sentences, Being Concise and Removing Redundancy, Avoiding Ambiguity and Vagueness

UNIT II PRESENTATION SKILLS 6

Clarifying Who Did What, Highlighting Your Findings, Hedging and Criticizing, Paraphrasing and Plagiarism, Sections of a Paper, Abstracts, Introduction

UNIT III TITLE WRITING SKILLS 6

Key skills are needed when writing a Title, key skills are needed when writing an Abstract, key skills are needed when writing an Introduction, skills needed when writing a Review of the Literature, Methods, Results, Discussion, Conclusions, The Final Check

UNIT IV RESULT WRITING SKILLS 6

Skills are needed when writing the Methods, skills needed when writing the Results, skills are needed when writing the Discussion, skills are needed when writing the Conclusions

UNIT V VERIFICATION SKILLS 6

Useful phrases, checking Plagiarism, how to ensure paper is as good as it could possibly be the first- time submission

TOTAL: 30 PERIODS

COURSE OUTCOMES:

CO1 –Understand that how to improve your writing skills and level of readability
CO2 – Learn about what to write in each section

CO3 – Understand the skills needed when writing a Title
CO4 – Understand the skills needed when writing the Conclusion
CO5 – Ensure the good quality of paper at very first-time submission

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1										✓		✓
CO2										✓		✓
CO3										✓		✓
CO4										✓		✓
CO5										✓		✓

REFERENCES

1. Adrian Wallwork , English for Writing Research Papers, Springer New York Dordrecht Heidelberg London, 2011
2. Day R How to Write and Publish a Scientific Paper, Cambridge University Press 2006
3. Goldbort R Writing for Science, Yale University Press (available on Google Books) 2006
4. Highman N, Handbook of Writing for the Mathematical Sciences, SIAM. Highman's book 1998.

AX5092 DISASTER MANAGEMENT L T P C
2 0 0 0

COURSE OBJECTIVES :

- Summarize basics of disaster
- Explain a critical understanding of key concepts in disaster risk reduction and humanitarian response.
- Illustrate disaster risk reduction and humanitarian response policy and practice from multiple perspectives.
- Describe an understanding of standards of humanitarian response and practical relevance in specific types of disasters and conflict situations.
- Develop the strengths and weaknesses of disaster management approaches

UNIT I INTRODUCTION 6

Disaster: Definition, Factors and Significance; Difference between Hazard and Disaster; Natural and Manmade Disasters: Difference, Nature, Types and Magnitude.

UNIT II REPERCUSSIONS OF DISASTERS AND HAZARDS 6

Economic Damage, Loss of Human and Animal Life, Destruction Of Ecosystem. Natural Disasters: Earthquakes, Volcanisms, Cyclones, Tsunamis, Floods, Droughts And Famines, Landslides And Avalanches, Man-made disaster: Nuclear Reactor Meltdown, Industrial Accidents, Oil Slicks And Spills, Outbreaks Of Disease And Epidemics, War And Conflicts.

UNIT III DISASTER PRONE AREAS IN INDIA 6

Study of Seismic Zones; Areas Prone To Floods and Droughts, Landslides And Avalanches; Areas Prone To Cyclonic and Coastal Hazards with Special Reference To Tsunami; Post-Disaster Diseases and Epidemics

UNIT IV DISASTER PREPAREDNESS AND MANAGEMENT 6

Preparedness: Monitoring Of Phenomena Triggering a Disaster or Hazard; Evaluation of Risk: Application of Remote Sensing, Data from Meteorological And Other Agencies, Media Reports: Governmental and Community Preparedness.

UNIT V RISK ASSESSMENT 6

Disaster Risk: Concept and Elements, Disaster Risk Reduction, Global and National Disaster Risk Situation. Techniques of Risk Assessment, Global Co-Operation in Risk Assessment and Warning, People's Participation in Risk Assessment. Strategies for Survival

TOTAL : 30 PERIODS

COURSE OUTCOMES:

CO1: Ability to summarize basics of disaster
CO2: Ability to explain a critical understanding of key concepts in disaster risk reduction and humanitarian response.
CO3: Ability to illustrate disaster risk reduction and humanitarian response policy and practice from multiple perspectives.
CO4: Ability to describe an understanding of standards of humanitarian response and practical relevance in specific types of disasters and conflict situations.
CO5: Ability to develop the strengths and weaknesses of disaster management approaches

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓											
CO2	✓											
CO3	✓	✓	✓									
CO4	✓	✓	✓									
CO5	✓	✓	✓									

REFERENCES

1. Goel S. L., Disaster Administration And Management Text And Case Studies",Deep & Deep Publication Pvt. Ltd., New Delhi,2009.
2. NishithaRai, Singh AK, "Disaster Management in India: Perspectives, issues and strategies "'New Royal book Company,2007.
3. Sahni, PardeepEt.Al. ," Disaster Mitigation Experiences And Reflections", Prentice Hall OfIndia, New Delhi,2001.

AX5093 SANSKRIT FOR TECHNICAL KNOWLEDGE L T P C
2 0 0 0

COURSE OBJECTIVES:

- Illustrate the basic sanskrit language.
- Recognize sanskrit, the scientific language in the world.
- Appraise learning of sanskrit to improve brain functioning.
- Relate sanskrit to develop the logic in mathematics, science & other subjects enhancing the memory power.
- Extract huge knowledge from ancient literature.

UNIT I ALPHABETS 6

Alphabets in Sanskrit

UNIT II TENSES AND SENTENCES 6

Past/Present/Future Tense - Simple Sentences

UNIT III ORDER AND ROOTS 6

Order - Introduction of roots

UNIT IV SANSKRIT LITERATURE 6

Technical information about Sanskrit Literature

UNIT V TECHNICAL CONCEPTS OF ENGINEERING 6

Technical concepts of Engineering-Electrical, Mechanical, Architecture, Mathematics

TOTAL: 30 PERIODS

COURSE OUTCOMES:

- CO1 - Understanding basic Sanskrit language.
- CO2 - Write sentences.
- CO3 - Know the order and roots of Sanskrit.
- CO4 - Know about technical information about Sanskrit literature.
- CO5 - Understand the technical concepts of Engineering.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1										✓		✓
CO2										✓		✓
CO3												✓
CO4												✓
CO5												✓

REFERENCES

1. "Abhyaspustakam" – Dr. Vishwas, Samskrita-Bharti Publication, New Delhi
2. "Teach Yourself Sanskrit" Prathama Deeksha-Vempati Kutumbshastri, Rashtriya Sanskrit Sansthanam, New Delhi Publication
3. "India's Glorious Scientific Tradition" Suresh Soni, Ocean books (P) Ltd., New Delhi, 2017.

AX5094 VALUE EDUCATION L T P C

2 0 0 0

COURSE OBJECTIVES:

Students will be able to

- Understand value of education and self-development
- Imbibe good values in students
- Let the should know about the importance of character

UNIT I

Values and self-development–Social values and individual attitudes. Work ethics, Indian vision of humanism. Moral and non-moral valuation. Standards and principles. Value judgements

UNIT II

Importance of cultivation of values. Sense of duty. Devotion, Self-reliance. Confidence, Concentration. Truthfulness, Cleanliness. Honesty, Humanity. Power of faith, National Unity. Patriotism. Love for nature, Discipline

UNIT III

Personality and Behavior Development-Soul and Scientific attitude. Positive Thinking. Integrity and discipline. Punctuality, Love and Kindness. Avoid fault Thinking. Free from anger, Dignity of labour.

Universal brother hood and religious tolerance. True friendship. Happiness Vs suffering, love for truth. Aware of self-destructive habits. Association and Cooperation. Doing best for saving nature

UNIT IV

Character and Competence–Holy books vs Blind faith. Self-management and Good health. Science of reincarnation. Equality, Nonviolence, Humility, Role of Women. All religions and same message. Mind your Mind, Self-control. Honesty, Studying effectively.

TOTAL: 30 PERIODS

COURSE OUTCOMES:

Students will be able to

- Knowledge of self-development.
- Learn the importance of Human values.
- Developing the overall personality.

SUGGESTED READING

1. Chakroborty, S.K."Values and Ethics for organizations Theory and practice", Oxford University Press, New Delhi

AX5095 CONSTITUTION OF INDIA L T P C
2 0 0 0

COURSE OBJECTIVES:

Students will be able to:

- Understand the premises informing the twin themes of liberty and freedom from a civil rights perspective.
- To address the growth of Indian opinion regarding modern Indian intellectuals' constitutional
- Role and entitlement to civil and economic rights as well as the emergence nation hood in the early years of Indian nationalism.
- To address the role of socialism in India after the commencement of the Bolshevik Revolutionin1917and its impact on the initial drafting of the Indian Constitution.

UNIT I HISTORY OF MAKING OF THE INDIAN CONSTITUTION:

History, Drafting Committee, (Composition & Working)

UNIT II PHILOSOPHY OF THE INDIAN CONSTITUTION:

Preamble, Salient Features

UNIT III CONTOURS OF CONSTITUTIONAL RIGHTS AND DUTIES:

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

UNIT IV ORGANS OF GOVERNANCE:

Parliament, Composition, Qualifications and Disqualifications, Powers and Functions, Executive, President, Governor, Council of Ministers, Judiciary, Appointment and Transfer of Judges, Qualifications, Powers and Functions.

UNIT V LOCAL ADMINISTRATION:

District's Administration head: Role and Importance, • Municipalities: Introduction, Mayor and role of Elected Representative, CEO, Municipal Corporation. Pachayati raj: Introduction, PRI: Zila Pachayat. Elected officials and their roles, CEO Zila Pachayat: Position and role. Block level: Organizational Hierarchy (Different departments), Village level: Role of Elected and Appointed officials, Importance of grass root democracy.

UNIT VI ELECTION COMMISSION:

Election Commission: Role and Functioning. Chief Election Commissioner and Election Commissioners - Institute and Bodies for the welfare of SC/ST/OBC and women.

TOTAL: 30 PERIODS

COURSE OUTCOMES:

Students will be able to:

- Discuss the growth of the demand for civil rights in India for the bulk of Indians before the arrival of Gandhi in Indian politics.
- Discuss the intellectual origins of the framework of argument that informed the conceptualization

- of social reforms leading to revolution in India.
- Discuss the circumstances surrounding the foundation of the Congress Socialist Party[CSP] under the leadership of Jawaharlal Nehru and the eventual failure of the proposal of direct elections through adult suffrage in the Indian Constitution.
- Discuss the passage of the Hindu Code Bill of 1956.

SUGGESTED READING

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

AX5096 PEDAGOGY STUDIES L T P C
2 0 0 0

COURSE OBJECTIVES

Students will be able to:

- Review existing evidence on there view topic to inform programme design and policy
- Making under taken by the DfID, other agencies and researchers.
- Identify critical evidence gaps to guide the development.

UNIT I INTRODUCTION AND METHODOLOGY:

Aims and rationale, Policy background, Conceptual framework and terminology - Theories of learning, Curriculum, Teacher education - Conceptual framework, Research questions **-** Overview of methodology and Searching.

UNIT II INTRODUCTION AND METHODOLOGY:

Aims and rationale, Policy background, Conceptual framework and terminology - Theories of learning, Curriculum, Teacher education - Conceptual framework, Research questions **-** Overview of methodology and Searching.

UNIT III THEMATIC OVERVIEW

Pedagogical practices are being used by teachers in formal and informal classrooms in developing countries - Curriculum, Teacher education.

UNIT IV EVIDENCE ON THE EFFECTIVENESS OF PEDAGOGICAL PRACTICES

Methodology for the in depth stage: quality assessment of included studies - How can teacher education (curriculum and practicum) and the school curriculum and guidance materials best support effective pedagogy? - Theory of change - Strength and nature of the body of evidence for effective pedagogical practices - Pedagogic theory and pedagogical approaches - Teachers' attitudes and beliefs and Pedagogic strategies.

UNIT V PROFESSIONAL DEVELOPMENT

Professional development: alignment with classroom practices and follow up support - Peer support - Support from the head teacher and the community - Curriculum and assessment - Barriers to learning: limited resources and large class sizes

UNIT VI RESEARCH GAPS AND FUTURE DIRECTIONS

Research design – Contexts – Pedagogy - Teacher education - Curriculum and assessment - Dissemination and research impact.

TOTAL: 30 PERIODS

COURSE OUTCOMES:

Students will be able to understand:

- What pedagogical practices are being used by teachers informal and informal classrooms in developing countries?
- What is the evidence on the effectiveness of these pedagogical practices, in what conditions, and with what population of learners?
- How can teacher education (curriculum and practicum) and the school curriculum and guidance materials best support effective pedagogy?

SUGGESTED READING

1. Ackers J, HardmanF (2001) Classroom interaction in Kenyan primary schools, Compare, 31(2): 245-261.
2. Agrawal M (2004)Curricular reform in schools: The importance of evaluation, Journal of Curriculum Studies, 36(3):361-379.
3. Akyeampong K (2003) Teacher training in Ghana-does it count? Multi-site teacher education research project (MUSTER) country report 1.London:DFID.
4. Akyeampong K, Lussier K, Pryor J, Westbrook J (2013) Improving teaching and learning of basic maths and reading in Africa: Does teacher preparation count? International Journal Educational Development, 33(3): 272–282.
5. Alexander RJ(2001) Culture and pedagogy: International comparisons in primary education. Oxford and Boston: Blackwell.
6. Chavan M(2003) Read India: Amass scale, rapid, 'learning to read' campaign.
7. www.pratham.org/images/resource%20working%20paper%202.pdf

AX5097	STRESS MANAGEMENT BY YOGA	L	T	P	C
		2	0	0	0

COURSE OBJECTIVES

- To achieve overall health of body and mind
- To overcome stress

UNIT I

Definitions of Eight parts of yoga.(Ashtanga)

UNIT II

Yam and Niyam - Do's and Don't's in life - i) Ahinsa, satya, astheya, bramhacharya and aparigraha, ii) Ahinsa, satya, astheya, bramhacharya and aparigraha.

UNIT III

Asan and Pranayam - Various yog poses and their benefits for mind & body - Regularization of breathing techniques and its effects-Types of pranayam

TOTAL: 30 PERIODS

COURSE OUTCOMES

Students will be able to:

- Develop healthy mind in a healthy body thus improving social health also
- Improve efficiency

SUGGESTED READING

1. 'Yogic Asanas for Group Tarining-Part-I":Janardan Swami Yoga bhyasi Mandal, Nagpur
2. "Rajayoga or conquering the Internal Nature" by Swami Vivekananda, Advaita Ashrama (Publication Department), Kolkata

AX5098	PERSONALITY DEVELOPMENT THROUGH LIFE ENLIGHTENMENT SKILLS	L	T	P	C
		2	0	0	0

COURSE OBJECTIVES:

- To learn to achieve the highest goal happily
- To become a person with stable mind, pleasing personality and determination
- To awaken wisdom in students

UNIT I

Neetisatakam-holistic development of personality - Verses- 19,20,21,22 (wisdom) - Verses-29,31,32 (pride & heroism) – Verses- 26,28,63,65 (virtue) - Verses- 52,53,59 (dont's) - Verses-71,73,75,78 (do's)

UNIT II

Approach to day to day work and duties - Shrimad Bhagwad Geeta: Chapter 2-Verses 41, 47,48 - Chapter 3-Verses 13, 21, 27, 35 Chapter 6-Verses 5,13,17,23, 35 - Chapter 18-Verses 45, 46, 48.

UNIT III

Statements of basic knowledge - Shrimad Bhagwad Geeta: Chapter2-Verses 56, 62, 68 Chapter 12 -Verses 13, 14, 15, 16,17, 18 - Personality of role model - shrimad bhagwad geeta - Chapter2-Verses 17, Chapter 3-Verses 36,37,42 - Chapter 4-Verses 18, 38,39 Chapter18 – Verses 37,38,63

TOTAL: 30 PERIODS

COURSE OUTCOMES:

Students will be able to

- Study of Shrimad-Bhagwad-Geeta will help the student in developing his personality and achieve the highest goal in life
- The person who has studied Geeta will lead the nation and mankind to peace and prosperity
- Study of Neet is hatakam will help in developing versatile personality of students.

SUGGESTED READING

1. Gopinath, Rashtriya Sanskrit Sansthanam P, Bhartrihari's Three Satakam, Niti-sringar-vairagya, New Delhi,2010
2. Swami Swarupananda , Srimad Bhagavad Gita, Advaita Ashram, Publication Department, Kolkata, 2016.