REGULATIONS AND SYLLABUS
(University Department)

(For the candidates admitted from the academic year 2021-2022 onwards)

MASTER OF TECHNOLOGY IN ENERGY TECHNOLOGY

(Under Choice Based Credit System)

DEPARTMENT OF ENERGY SCIENCE AND TECHNOLOGY

PERIYAR UNIVERSITY

SCHOOL OF ENERGY AND ENVIRONMENTAL SCIENCES

(NAAC A Grade -State University- NIRF Rank 83, ARIIA Rank 4)

SALEM– 636 011

TAMIL NADU

Regulations & Scheme

M.Tech., Energy Technology

Choice Based Credit System (CBCS) Regulation,

Scheme and Syllabus

(W.e.f.2021-2022onwards)

1. Eligibility for Admission

Candidate who has passed the B.E/B.Tech degree in Aeronautical/Agricultural/ Automobile/ Chemical Engineering/ Civil/ Electrical/ Electronics/ Energy and Environment/ Instrumentation/ Mechanical/ Mechatronics/ Nano Technology or M.Sc., degree in Physics/ Chemistry/ Energy / Material Science of this University or any other University shall be eligible for admission to M.Tech., degree of this University

2. Mode of Selection

The admission is subject to the prevailing rules and regulations for PG admission of this University and also as per the norms of Tamil Nadu Government.

3. Duration of the Course

The duration of the M.Tech., degree shall be two years consist of four semesters. Each semester consists of 90 working days.

4. Distribution of Credit Points

The minimum credit requirement for M.Tech., degree shall be 90 Credits. The break-up of credits for the Programme is as follows;

- Core Courses : 66 credits
- Elective Courses : 20 credits
- Supportive Courses : 06 credits

5. Course of Study

The course of study for the M.Tech., degree shall be in Energy Technology (CBCS) with internal assessment according to syllabi prescribed from time to time.

5.1 Components of Internal Examination

The allotment of marks and scheme of examination as follows;

Internal Tests (Best 1 out of 2)	05 Marks
Model Examination	05 Marks
Seminar	05 Marks
Assignment	05 Marks
Attendance	05 Marks
Total	25 Marks

5.2 Theory Core Paper

External	75 Marks
Internal	25 Marks
Total	100 Marks
Duration of Examination	3 Hours

5.3 Practical Internal &External

Model Practical	30 Marks
Record	05 Marks
Viva Voce	05 Marks
Internal Total	40 Marks
External	60 Marks
Total	100 Marks

5.4 Marks allotment for attendance as follows

% of attendance	Marks
96% - 100%	5
91% - 95%	4
86%- 90%	3
81% - 85%	2
75% - 80%	1
Below 75%	No marks

6. Details of Project Marks

Project work	**Internal (40 Marks)**			**External (60 marks)**			
Phase I	Review I	Review II	Review III	Thesis Evaluation (External)	Viva –voice 45 Marks		
					Supervisor	External	Internal
	10	10	20	15	15	15	15

Project work	**Internal (80 Marks)**			**External (120 marks)**			
Phase II	Review I	Review II	Review III	Thesis Evaluation (External)	Viva –voice 90 Marks		
					Supervisor	External	Internal
	20	20	40	30	30	30	30

The project work is an important component of post graduate Programme. The Project work consists of Phase – I and Phase – II. The Phase – I is to be undertaken during III semester and Phase – II which is a continuation of Phase – I is to be undertaken during IV semester.

The Project work for Phase II shall be pursue for a minimum of 90 days during the final semester. Students may be permitted to carried out project work either internal or external mode i.e, Industrial / Research Organization, etc., on the recommendations of the Head of the Department. In case of external, the Project work shall be jointly guided by a supervisor of the department and an expert as joint supervisor from the organization and the student shall be instructed to meet the supervisor periodically and attend the review committee meetings for evaluating the progress.

7. Question Paper Pattern

Time: 3 Hrs **Maximum Marks: 75**

PART – A (20X1= 20 Marks)
Objective Type Questions
PART – B (3X5= 15 Marks)
Analytical Questions Any 3 out of 5 (One question from each Unit)
PART – C (5X8= 40 Marks)
Either or Type descriptive questions (Two questions from each Unit)

8. Passing Minimum

1. There shall be no Passing Minimum Marks for Internal.
2. For External Examination, Passing Minimum shall be of 50% (Fifty Percentage) of the maximum marks prescribed for the paper.
3. In aggregate (External +Internal) the passing minimum shall be of 50% for each Paper/Practical/Project and Viva-voce.
4. Grading shall be based on overall marks obtained (internal + external).

9. Classification of Successful Candidate

CGPA	Grade	Classification of final result
9.5-10.0	O+	First Class with Exemplary
9.0 and above but below 9.5	O	
8.5 and above but below 9.0	D++	First Class with Distinction
8.0 and above but below 8.5	D+	
7.5 and above but below 8.0	D	
7.0 and above but below 7.5	A++	First Class
6.5 and above but below 7.0	A+	
6.0 and above but below 6.5	A	
5.5 and above but below 6.0	B+	Second Class
5.0 and above but below 5.5	B	
0.0 and above but below 5.5	U	Re-appear

10. Marks and Grades

Range of Marks	Grade points	Letter Grade	Description
90 – 100	9.0 – 10.0	O	**Outstanding**
80-89	8.0 – 8.9	D+	**Excellent**
75-79	7.5 – 7.9	D	**Distinction**
70-74	7.0 – 7.4	A+	**Very Good**
60-69	6.0 – 6.9	A	**Good**
50-59	5.0 – 5.9	B	**Average**
00-49	0.0	U	**Re-Appear**
Absent	**0.0**	AAA	**Absent**

11. Internship

The students may undergo internship training at Research organization / University/ industry for a period as specified in the curriculum during summer vacation. In this case the training has to be undergone continuously for the entire period.

Duration of Internship	Credits
2 Weeks to 4 weeks	2

At the end of internship, the student shall submit a report. The Viva-Voce Examination will be conducted by a three-member committee constituted by the Head of the Department. The committee comprises of one expert from an industry/

organization and two members (Coordinator and supervisor) from the Department. Certificates (issued by the Organization) submitted by the student shall be attached to the mark list and sent to the Controller of Examinations by the Head of the Department.

INTERNSHIP TRAINING

EVALUATION

Report	Presentation	Viva Voce	Total
40	30	30	100

12. Supportive Paper

Supportive paper should be offered in second and third semesters. Students are expected to opt Supportive Course (Non major elective) offered by other departments. Students can earn three credits from supportive course.

13. Swayam Course

SWAYAM is a Programme initiated by Government of India and designed to achieve the three cardinal principles of Education Policy namely access, equity, and quality. The objective of this effort is to take the best teaching learning resources to all, including the most disadvantaged. SWAYAM seeks to bridge the digital divide for students who have hitherto remained untouched by the digital revolution and have not been able to join the mainstream of the knowledge economy. The courses hosted on SWAYAM are in 4 quadrants – (1) video lecture, (2) specially prepared reading material that can be downloaded/printed (3) self-assessment tests through tests and quizzes and (4) an online discussion forum for clearing the doubts. Steps have been taken to enrich the learning experience by using audio-video and multi-media and state of the art pedagogy / technology. In order to ensure best quality content are produced and delivered, nine National Coordinators have been appointed: They are AICTE for self-paced and international courses, NPTEL for engineering, UGC for non-technical post-graduation education, CEC for under-graduate education, NCERT and NIOS for school education, IGNOU for out-of-the school students, IIMB for management studies and NITTTR for Teacher Training Programme. Courses delivered through SWAYAM are available free of cost to the learners, however, students wanting certifications if they register will be offered a certificate on successful completion of the course, for a small fee. At the end of each course, there will be an assessment of the student through proctored examination and the marks/ grades secured in this exam could be transferred to the academic record of the students.

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs):

The Energy Technology 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 energy sector and advance to significant positions of leadership in their Profession.

II. Inclination towards advanced research for mitigating the shortcomings in energy systems.

III. Ascending as an energy consultant for providing solutions towards improving the efficacy of energy systems.

IV. Become a successful entrepreneur and be a part of a supply chain or manufacture or market energy products for sustainable development.

V. Lead an ethical life by engaging in lifelong learning experiences for developing environmentally benign and economically affordable energy products for societal upliftment

PROGRAMME OUTCOMES (POs):

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

PO	Graduate Attribute	Programme Outcome
1	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	Function in a multidisciplinary team.
10	Communication	Proficiency in oral and written Communication.
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 energy sourcing, generation, distribution, consumption, and emission patterns of India Vs Globe, apart from computation of plant load factor, efficiency, quantification of emissions along with cost of power generation from various energy sources
2. To carry out energy audit in Industries by accounting its energy consumption pattern, determining its specific energy consumption, diagnosing the causes for deviation from the industry benchmarks and suggestions for improving the performance of the plant
3. To instill ability to use knowledge in various domains to identify research gaps and ideate innovations by simulation of energy systems using software such as MATLAB, ANSYS- CFD, Fluent, TRNSYS, PV-SYST

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	PO01	PO02	PO03	PO04	PO05	PO06	PO07	PO08	PO09	PO10	PO11	PO12
I YEAR	Semester 1	Energy Scenario, Policy and Environment	✓			✓		✓	✓			✓	✓	✓
		Fluid Flow and Heat Transfer	✓	✓	✓	✓		✓	✓					✓
		Thermodynamic Analysis of Energy Systems	✓	✓	✓	✓		✓	✓					✓
		Energy Auditing and Management	✓			✓		✓	✓	✓	✓	✓	✓	✓
		Elective I												
		Energy Laboratory	✓	✓		✓		✓			✓			✓
	Semester 2	Energy Efficiency in Thermal and Electrical Utilities	✓			✓		✓	✓	✓	✓	✓	✓	✓
		Power Generation and System Planning	✓			✓		✓	✓		✓		✓	✓
		Solar Energy for Industrial Process Heat	✓	✓	✓	✓		✓	✓		✓	✓	✓	✓
		Computational Fluid Dynamics	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓
		Elective II												
		Supportive												
		Analysis and Simulation Laboratory	✓	✓		✓		✓			✓			✓
II YEAR	Semester 3	Advanced Power Plant Engineering	✓	✓	✓	✓	✓	✓	✓					✓
		Advanced Energy Storage technologies	✓	✓	✓	✓	✓	✓	✓				✓	✓
		Elective III												
		Supportive												
		Internship												
		Human Rights												
		Project work Phase I	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Semester 4	Nanomaterials for Energy Applications	✓	✓	✓	✓	✓	✓	✓					✓
		Elective IV												
		Elective V												
		Project Work Phase II	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

PERIYAR UNIVERSITY, SALEM
UNIVERSITY DEPARTMENT REGULATIONS – 2021
CHOICE BASED CREDIT SYSTEM
M.TECH. ENERGY TECHNOLOGY

CURRICULUM AND SYLLABUS

SEMESTER I

S. No	Course Code	Course Title	Category	Contact Periods	L	T	P	C
1	21UPEST2C01	Energy Scenario, Policy and Environment	PC	5	4	1	0	4
2	21UPEST2C02	Fluid Flow and Heat Transfer	PC	5	4	1	0	4
3	21UPEST2C03	Thermodynamic Analysis of Energy Systems	PC	5	4	1	0	4
4	21UPEST2C04	Energy Auditing and Management	PC	5	4	1	0	4
5	-	Elective I	PE	4	4	0	0	4
PRACTICALS								
6	21UPEST2C05	Energy Laboratory	PC	3	0	0	3	2
			TOTAL	**27**	**20**	**4**	**3**	**22**

SEMESTER II

S. No	Course Code	Course Title	Category	Contact Periods	L	T	P	C
1	21UPEST2C06	Energy Efficiency in Thermal and Electrical Utilities	PC	4	4	0	0	4
2	21UPEST2C07	Power Generation and System Planning	PC	4	4	0	0	4
3	21UPEST2C08	Solar Energy for Industrial Process Heat	PC	4	4	0	0	4
4	21UPEST2C09	Computational Fluid Dynamics	PC	5	4	1	0	4
5	-	Elective II	PE	4	4	0	0	4
6	-	Supportive	NM	3	3	0	0	3
7	06PHR01	HUMAN RIGHTS	-	0	0	0	0	0
PRACTICALS								
8	21UPEST2C10	Analysis and Simulation Laboratory Engineering	PC	3	0	0	3	2
			TOTAL	**27**	**23**	**1**	**3**	**25**

SEMESTER III

S. No	Course Code	Course Title	Category	Contact Periods	L	T	P	C
THEORY								
1	21UPEST2C11	Advanced Power Plant Engineering	PC	4	4	0	0	4
2	21UPEST2C12	Advanced Energy Storage technologies	PC	4	4	0	0	4
3	-	Elective III	PE	4	4	0	0	4
4	-	Supportive	NM	3	3	0	0	3
5	21UPEST2C13	Internship	PC	0	0	0	0	2
Project Work								
6	21UPEST2C14	Project Work Phase I	PC	14	0	0	14	7
			TOTAL	**29**	**15**	**0**	**14**	**24**

SEMESTER IV

S. No	Course Code	Course Title	Category	Contact Periods	L	T	P	C
THEORY								
1	21UPEST1C15	Nanomaterials for Energy Applications	PC	4	4	0	0	4
2	-	Elective IV	PE	4	4	0	0	4
3	-	Elective V	PE	4	4	0	0	4
Project Work								
4	21UPEST1C16	Project Work Phase II	PC	18	0	0	18	9
			TOTAL	**30**	**12**	**0**	**18**	**21**

TOTAL CREDITS TO BE EARNED FOR THE AWARD OF DEGREE = 90

Swayam Course Details

S. No	Course Code	Course Title	Category	Contact Periods	L	T	P	C
1	SWAYAM Course – I (I Year)							
2	SWAYAM Course –II (II Year)							

PROFESSIONAL CORE (PC)

S.No	Course Code	Course Title	Category	Contact Periods	L	T	P	C
1.	21UPEST2C01	Energy Scenario, Policy and Environment	PC	4	4	1	0	4
2.	21UPEST2C02	Fluid Flow and Heat Transfer	PC	4	4	1	0	4
3.	21UPEST2C03	Thermodynamic Analysis of Energy Systems	PC	4	4	1	0	4
4.	21UPEST2C04	Energy Auditing and Management	PC	4	4	1	0	4
5.	21UPEST2C05	Energy Laboratory	PC	3	0	0	3	2
6.	21UPEST2C06	Energy Efficiency in Thermal and Electrical Utilities	PC	4	4	0	0	4
7.	21UPEST2C07	Power Generation and System Planning	PC	4	4	0	0	4
8.	21UPEST2C08	Solar Energy for Industrial Process Heat	PC	4	4	0	0	4
9.	21UPEST2C09	Computational Fluid Dynamics	PC	4	4	1	0	4
10.	21UPEST2C10	Analysis and Simulation Laboratory Engineering	PC	4	0	0	0	2
11.	21UPEST2C11	Advanced Power Plant Engineering	PC	4	4	0	0	4
12.	21UPEST2C12	Advanced Energy Storage technologies	PC	4	4	0	0	4
13.	21UPEST2C13	Internship	PC	0	0	0	0	2
14.	21UPEST2C14	Project Work Phase I	PC	14	0	0	14	7
15.	21UPEST1C15	Nanomaterials for Energy Applications	PC	4	0	0	0	4
16.	21UPEST1C16	Project Work Phase II	PC	30	0	0	30	15

PROFESSIONAL ELECTIVE (PE)

S. No	Course Code	Course Title	Category	Contact Periods	L	T	P	C
Semester-I (Elective – I)								
1.	21UPEST2E01	Solar Energy Technologies	PE	4	4	0	0	4
2.	21UPEST2E02	Nuclear Energy Technology	PE	4	4	0	0	4
3.	21UPEST2E03	Power Electronics for Renewable Energy Systems	PE	4	4	0	0	4
4.	21UPEST2E04	Environmental Engineering and Pollution Control	PE	4	4	0	0	4
Semester -II (Elective – II)								
5.	21UPEST2E05	Wind Energy Conversion Systems	PE	4	4	0	0	4
6.	21UPEST2E06	Electrical Drives and Controls	PE	4	4	0	0	4
7.	21UPEST2E07	Fuel and Combustion	PE	4	4	0	0	4
8.	21UPEST2E08	Principles and Applications of Hydrogen Storage	PE	4	4	0	0	4
Semester -III (Elective – III)								
9.	21UPEST2E09	Waste Management and Energy Recovery Techniques	PE	4	4	0	0	4
10.	21UPEST2E10	Design and Analysis of Turbo Machines	PE	4	4	0	0	4
11.	21UPEST2E11	Modeling and Analysis of Energy Systems	PE	4	4	0	0	4
12.	21UPEST2E12	Cogeneration and Waste Heat Recovery Systems	PE	4	4	0	0	4
Semester -IV (Elective – IV)								
13.	21UPEST2E13	Fluidized Bed Systems	PE	4	4	0	0	4
14.	21UPEST2E14	Hydro Power Systems	PE	4	4	0	0	4
15.	21UPEST2E15	Smart Grid Technologies	PE	4	4	0	0	4
16.	21UPEST2E16	Solar Refrigeration and Air-conditioning	PE	4	4	0	0	4
Semester -IV (Elective – V)								
17.	21UPEST2E17	Innovation and Entrepreneurship	PE	4	4	0	0	4
18.	21UPEST2E18	Bio Energy Technologies	PE	4	4	0	0	4
19.	21UPEST2E19	Energy Efficient Buildings Design	PE	4	4	0	0	4
20.	21UPEST2E20	Energy Forecasting, Modeling and Project Management Technique	PE	4	4	0	0	4

NON-MAJOR ELECTIVE COURSES (NM)

S. No	Course Code	Course title	Category	Contact Periods	L	T	P	C
1	21UPEST2S01	Basic Concepts in Energy Sciences	NM	3	3	0	0	3
2	21UPEST2S02	Climate Change and CO_2 Emission Assessment	NM	3	3	0	0	3
3	21UPEST2S03	Energy and Environmental Impacts	NM	3	3	0	0	3
4	21UPEST2S04	Erection and Maintenance of Refrigeration and Air-Conditioning Equipment	NM	3	3	0	0	3
5	21UPEST2S05	Green Concepts in Building	NM	3	3	0	0	3

VALUE ADDED COURSE

S. No	Course Code	Course title	Category	Contact Periods	L	T	P	C
1	21UPESTVA01	ALTERNATE FUELS AND EMISSIONS	**VA**	30	30	0	0	0
2	21UPESTVA02	BIOMASS AND ITS CONVERSION TECHNOLOGIES	**VA**	30	30	0	0	0
3	21UPESTVA03	MATERIALS FOR ENERGY APPLICATIONS	**VA**	30	30	0	0	0
4	21UPESTVA04	ELECTRIC VEHICLES	**VA**	30	30	0	0	0
5	21UPESTVA05	DESIGN THINKING	**VA**	30	30	0	0	0

21UPEST2C01 ENERGY SCENARIO, POLICY AND ENVIRONMENT

OBJECTIVES

- To understand the global energy scenario and types of energy resources
- To learn about the Indian energy demand and production
- To inculcate information on impact of energy on economy and development
- To understand the details on government policies in energy and
- To know measures the impact of energy savings on environment

UNIT I GLOBAL ENERGY SCENARIO

Role of energy in economic development and social transformation, - Energy sources and overall energy demand and availability - Energy Consumption in various sectors and its changing pattern - Non-Conventional and Conventional Energy Resources: Coal, Oil, Natural Gas, Nuclear Power and Hydroelectricity, Solar, wind and other renewable etc. - Energy Security, Energy Consumption and its impact on environmental climatic change

UNIT II INDIAN ENERGY SCENARIO

Energy resources & Consumption - Commercial and noncommercial forms of energy, Fossil fuels - Renewable sources including Bio-fuels in India and their utilization pattern in the past, present and future projections of consumption pattern, Sector wise energy consumption.

UNIT III IMPACT OF ENERGY ON ECONOMY AND DEVELOPMENT

Energy for Sustainable Development - Energy and Environmental policies - Need for use of new and renewable energy sources, present status and future of nuclear and renewable energy - Energy Policy Issues related Fossil Fuels, Renewable Energy, Power sector reforms, restructuring of energy supply sector, energy strategy for future.

UNIT IV ENERGY POLICY

Global energy issues - National & State level energy issues - National & State energy policy - Industrial energy policy - Energy security - Energy vision - Energy pricing & Impact of global variations - Energy productivity (National & Sector wise productivity).

UNIT V ENVIRONMENT

Concept of environment and ecology, various natural cycles in environment and ecology, effect of human activities on environment and ecology - Environmental Impact Assessment, Methodologies for environmental pollution prevention - Rules, regulations, laws etc. regarding environmental protection, pollution prevention and control, waste disposal etc. - Role of government, semi/quasi govt. and voluntary organizations.

OUTCOMES

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

- Understand the concepts of Non-Conventional and Conventional Energy Resources

- To get a familiar knowledge in energy scenario globally and locally
- To obtain statistics on Renewable sources
- To acquire information on government energy policies
- To get to know about the effects of energy demand on environment

REFERENCES

1. Energy for a sustainable world: Jose Goldenberg, Thomas Johansson, A.K.N.Reddy, Robert Williams (Wiley Eastern).
2. Energy policy: B.V.Desai (Weiley Eastern),
3. Energy and the Challenge of Sustainability, World energy assessment, UNDP New York, 2000.
4. AKN Reddy, RH Williams, TB Johansson, Energy after Rio, Prospects and challenges, UNDP, United Nations Publications, New York, 1997.
5. Renewable Energy, M.K. Ghosh Roy, Scientific International Pvt Ltd, 2015

CO	**PO**												**PSO**		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**1**	**2**	**3**
1	H	-	-	H	-	L	H	L	-	L	-	M	H	H	-
2	M	-	-	H	-	L	H	L	-	L	-	M	M	H	L
3	H	-	M	M	-	M	H	-	-	L	-	M	M	M	L
4	L	-	-	M	-	H	H	H	-	M	-	M	H	M	-
5	L	-	-	L	-	M	H	-	-	M	-	M	H	H	-

21UPEST2C02 FLUID FLOW AND HEAT TRANSFER

OBJECTIVES

- To lay the foundation for and improve the equations Euler and Bernoulli.
- To understand principles of fluid flow, incompressible and compressible
- To inculcate conduction analysis and heat transfer of gas radiation
- To learn the different heat and condensation transfer processes.
- To impart the knowledge of design of heat exchangers

UNIT I INTRODUCTION AND BASIC CONCEPTS

Classification of fluid flows - Fluid statics - Buoyancy and Stability - Fluids in rigid-body motion - Fluid Kinematics - Lagrangian and Eulerian descriptions - Flow patterns and Flow visualization- Vorticity and Rotationality- Conservation of mass - Bernoulli equation - General energy equation.

UNIT II ANALYSIS OF FLOW SYSTEMS

The Linear Momentum Equation - The Angular Momentum Equation - Internal Flow - Laminar and Turbulent Flows - Entrance Region - Laminar Flow in Pipes - Turbulent Flow in Pipes - Flow Rate and Velocity Measurement - The Stream Function - The Navier–Stokes Equation - External Flow - Drag and Lift

UNIT III CONDUCTION AND RADIATION HEAT TRANSFER

One-Dimensional Heat Conduction Equation - Steady Heat Conduction in Plane Walls - Heat Conduction in Cylinders and Spheres - Transient Heat Conduction - Lumped System Analysis - Radiation Heat Transfer: Black Surfaces, Diffuse, Gray - Thermal Radiation - Blackbody Radiation

UNIT IV HEAT TRANSFER AND HEAT EXCHANGERS

Boiling Heat Transfer- Pool Boiling -Flow Boiling - Condensation Heat Transfer - Film Condensation - Film Condensation Inside Horizontal Tubes - Dropwise Condensation - Types of Heat Exchangers - The Overall Heat Transfer Coefficient - Analysis of Heat Exchangers - The Log Mean Temperature Difference Method - The Effectiveness–NTU Method - Selection of Heat Exchangers.

UNIT V TURBULENT FORCED CONVECTIVE HEAT TRANSFER

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.

OUTCOMES

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

- Understand various types of fluid flow and able derive basic fundamental equations applied to fluid flow
- Apply correctly the conservation principles of mass, linear momentum, and energy to fluid flow systems.

- Solve the conduction and gas radiation heat transfer problems.
- Understand the turbulent forced convective heat transfer
- Design of heat exchanger according to industry requirements.

REFERENCES

1. Yunus A. Cengel, Afshin J. Ghajar, Heat and Mass Transfer: Fundamentals & Applications in SI Units, 6th Edition, McGraw-Hill Education, 2020
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21UPEST2C03 THERMODYNAMIC ANALYSIS OF ENERGY SYSTEMS

OBJECTIVES

- To understand the basic principles and scope of thermodynamics.
- To know principles of phase equilibrium in two-component and multi-component systems.
- To apply mass, energy and entropy balances to flow processes.
- To understand Stoichiometric for Complete combustion.
- Significance of IC Engines in thermodynamic.

UNIT I AVAILABILITY ANALYSIS AND THERMODYNAMIC PROPERTY RELATION

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 - Cp and Cv - Clausius Clapeyron equation, Joule – Thomson coefficient - Bridgeman tables for thermodynamic relations.

UNIT II REAL GAS BEHAVIOUR AND MULTI – COMPONENT SYSTEMS

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. Equilibrium in multi-phase systems.

UNIT III CHEMICAL THERMODYNAMICS AND EQUILIBRIUM

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

Combustion of Hydrocarbon Fuels - Heat of reaction, combustion and formation. Stoichiometric, fuel rich and oxygen rich reactions. Heating value of fuels - Application of energy equation to the combustion process - Explosion limits, flames and flammability limits - Diffusion and premixed flames.

UNIT V COMBUSTION PROCESS AND COMBUSTION CHAMBERS

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

OUTCOMES

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

-To categorize the performance of ideal gas, real gas and pure substance.
-To evaluate Stoichiometric generation during a thermodynamic process.

- To determine air fuel mixture during combustion.
- To know about the Combustion of Hydrocarbon Fuels
- To understand in detail about the combustion chamber configuration of IC Engines.

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21UPEST2C04 ENERGY AUDITING AND MANAGEMENT

OBJECTIVES

- To obtain information on Types & Forms of Energy
- To learn the process of forecasting energy utilization and energy loss rates.
- To acclimatize with power quality issues in energy management.
- To learn sufficient knowledge on energy monitoring methods and optimal regulations.
- To obtain knowledge on Instruments Used in Energy systems

UNIT I INTRODUCTION

Types & Forms of Energy - Primary / Secondary Energy Sources –Energy Conservation Act 2001- Electricity Act 2003 - Energy Auditing: Types, classifications, deliverables, barriers – Benchmarking - Roles & Responsibility of Energy Managers-Matching Energy Usage to Requirements-Fuel and Energy Substitution-Optimizing input energy requirements.

UNIT II ENERGY COSTING, MONITORING & TARGETING

Data & Information Analysis – Cost / Energy Share Diagram – Data Graphing – Electricity Billing: Components & Costs – kVA – Need & Control – Determination of kVA demand & Consumption – Time of Day Tariff – Power Factor Basics – Penalty Concept for PF – PF Correction – Wheeling and Banking - Demand Side Management – comparison on unit cost of power cost from various sources – steam cost from different sources-noneconomic factors

UNIT III METERING FOR ENERGY MANAGEMENT & POWER QUALITY ANALYSES

Instruments Used in Energy systems: Load and power factor measuring equipment, Wattmeter, flue gas analysis, Temperature and thermal loss measurements, air quality analysis etc. Relationships between parameters-Units of measure-Typical cost factors- Utility meters – Timing of meter disc for kilowatt measurement - Demand meters - Paralleling of current transformers - Instrument transformer burdens-Multitasking solid-state meters - Metering location vs. requirements – Net metering - Metering techniques and practical examples.

UNIT IV LIGHTING SYSTEMS & COGENERATION

Concept of lighting systems - The task and the working space - Light sources - Ballasts - Luminaries - Lighting controls - Optimizing lighting energy - Power factor and effect of harmonics on power quality - Cost analysis techniques - Lighting and energy standards Cogeneration: Forms of cogeneration - feasibility of cogeneration- extraction turbines and steam cycle of cogeneration- Electrical interconnection.

UNIT V INDUSTRIAL SAFETY

Evolution of modern safety concept- Safety policy - Safety Organization - line and staff functions for safety- Safety Committee- budgeting for safety

OUTCOMES

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

- Familiarized about the energy sources, energy acts, and energy auditing and energy management methods.
- Eligible to perform micro and macroeconomic forecasting of energy consumption and utilization.
- Involve in energy extraction and efficiency rate improvement through incorporation of hybrid systems.
- Adopt energy standards based on various acts officially established for qualitative and quantitative improvement in energy utilization.
- Acquired a knowledge about energy in economic view.

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21UPEST2C05 ENERGY LABORATORY

OBJECTIVES

- To gain practical knowledge on thermal energy Storage system using various PCM.
- To obtain the knowledge on working and characterization of Solar PV cell.
- To analyze the solar cell efficiency through solar cell simulator.
- To acquire the principle operation of biogas plant and analyze its constituents.
- To learn the working of Solar Hot Water heater.
- To characterize the properties of fuel.
- To assess the performance of Wind Energy Generator.
- To identify the concept of heat transfer in heat exchangers.
- To attain the methodology adopted for performance evaluation of various gadgets of renewable energy systems

LIST OF EXPERIMENTS

1. Evaluation of Heat loss and Efficiency in thermosyphonic mode of heat flow at different radiation level in Solar Flat Plate Water Heating System.
2. Conduct an experiment to obtain I-V and P-V characteristics of PV module with varying radiation level using Solar PV Training & Research System.
3. Performance analyses of PV module with various tilt angle using Solar PV Training & amp; Research System.
4. Effect of shading on the efficiency of PV module with regards to voltage current and power using Solar PV Training & Research System.
5. Performance assessment of Wind Energy Generator based on wind velocity.
6. Determination of the flash point of a given sample using Abel flash point apparatus.
7. Study Experiment on Nano Floating Drum Biogas Plant.
8. Experimental analysis on the percentage of biogas formed for the given amount of organic waste using bio gas analyzer.
9. Experimental Evaluation of a Paraffin wax as Phase Change Material for Thermal Energy Storage in TES Training System.
10. Experimental Evaluation of a fatty acid as Phase Change Material for Thermal Energy Storage in TES Training System.
11. Experimental Evaluation of a Paraffin wax and fatty acid (mixed) as Phase Change Material for Thermal Energy Storage during charging mode in TES Training System.
12. Experimental Evaluation of a Paraffin wax and fatty acid (mixed) as Phase Change Material for Thermal Energy Storage during discharging mode in TES Training System.
13. Determination the overall heat transfer coefficient in a plate type heat exchanger at different hot fluid flow rate.
14. Experimental analysis on efficiency of solar cell under varying light intensity using Solar Simulator-SS50 AAA.
15. A study experiment on tools used in the assessment of illuminance (lux meter), wind speed (anemometer), pH level (pH indicator), Humidity (humidity sensor), Temperature (K-Type Thermocouple), sound level (sound meter).

OUTCOMES

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

- To gain practical knowledge about Sensible heat storage, Latent heat storage, thermochemical heat storage in thermal Heat Storage systems.
- To gain knowledge about the operation of solar PV devices and their characterization.
- To evaluate solar cell performance using solar simulator.
- To gather biogas data from different types of organic wastes.

- To gain an understanding of how a solar hot water heater works.
- To evaluate the flash point of alternative fuel.
- To understand how to maximize the power output of a turbine.
- Analyze the factors influencing the efficiency and suggest methods for improving the adaptability and efficiency of renewable energy Systems.

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21UPEST2C06 ENERGY EFFICIENCY IN THERMAL AND ELECTRICAL UTILITIES

OBJECTIVES

- To learn importance fuel properties and combustion
- To Know the heat transfer modes in boiler and performance evaluation of direct and indirect method
- To understand the characteristics of steam traps and efficient utilization of steam
- To explicate important electrical equipment, electrical symbols, electricity billing and the losses associated with a motor
- To elucidate the improvement factors in lighting.

UNIT I FUELS AND COMBUSTION

Introduction to fuels - properties of fuel oil, coal and gas - storage, handling and preparation of fuels - principles of combustion - combustion of oil, coal and gas - draft system – combustion controls – Agro residue/biomass handling, preparation and combustion.

UNIT II BOILERS AND COGENERATION

Combustion in boilers - performances evaluation – direct and indirect method- analysis of losses - feed water treatment, blow down - boiler efficiency calculation - energy conservation opportunities. Cogeneration - principles & operation – Power Ratio - economics of cogeneration scheme – classification - heat balance - steam turbine efficiency

UNIT III STEAM SYSTEM

Properties of steam - assessment of steam distribution losses, steam leakages, steam trapping - condensate and flash steam recovery system - identifying opportunities for energy savings. Steam utilization - Performance assessment - thermo-compressor, steam pipe insulation - condensate pumping - steam dryers.

UNIT IV ELECTRIC MOTORS, FANS AND PUMPS

Electric motor types - losses in induction motors - motor efficiency, factors affecting motor performance - energy saving opportunities with energy efficient motors. Fans and Pumps – types - performance evaluation - efficient system operation - flow control strategies and energy conservation opportunities

UNIT V LIGHTING SYSTEM AND ENERGY EFFICIENCY DEVICES

Lighting sources - choice of lighting - luminance requirements and energy conservation avenues. New generation luminaries - Light Emitting Diodes (LEDs) - high efficiency street lighting. Maximum demand controllers – Automatic power factor controllers – Soft starters with energy saver - electronic ballast - occupancy sensors – energy efficient lighting controls

OUTCOMES

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

- Evaluate the performance of fuel and biomass under different operating conditions
- IBR definition of Boiler and Steam pipes and heat to power ratio.
- Condensate and flash steam recovery and energy efficiency opportunities in steam systems
- Acquire knowledge about electrical motor and flow control strategies.
- Understand the parameters and terminologies used in lighting systems.

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21UPEST2C07 POWER GENERATION AND SYSTEM PLANNING

OBJECTIVES

- To familiarize the students to the working of power plants based on different fuels
- To incorporate the knowledge of electrical power generation from Conventional sources
- To understand planning of power transmission and distribution
- To understand the Economics of Power generation and Utilization of Electrical Energy for various application.
- To understand the concept and design smart grid in modern power system

UNIT I CONVENTIONAL POWER GENERATION

Steam power plant - Selection of site - Generated Layout - coal and Ash Handling -Steam Generating Plants - Feed Make Circuit - Cooling Towers - Turbine Governing -Hydro Power Plant-Selection of Site - Classification Layout Governing of Turbines -Nuclear Power Plants - Selection of Site - Classification Layout Governing of Turbines - Nuclear Power Plants - Gas Turbine Plants.

UNIT II NON-CONVENTIONAL POWER GENERATION

Wind power generation - characteristics of wind power-design of windmills - Tidal power generation - Single and two-basin systems -Turbines for tidal power - Solar power generation - Energy from biomass, biogas and waste

UNIT III POWER SYSTEM PLANNING

Generation Planning - Load Forecasting; Forecasting methodology - Energy forecasting – peak demand forecasting - Capacity Resource Planning - Transmission Planning - Rotor-Angle Stability - Voltage Stability - Frequency Stability - Distribution System Planning – Load Forecasting - Planning for Reliability.

UNIT IV IMPACT OF SOLAR PV

Impact of Variable Renewable Energy Generation - Implications on Generation Planning - Implications for Transmission Planning - Modeling PV Inverters for Transmission Planning - Implications for Distribution Planning and Engineering - Feeder Voltage Regulation - Ungrounded Source of Voltage.

UNIT V CONCEPT AND FUNCTION OF SMART GRID

Opportunities & Barriers of Smart Grid, Difference between conventional & smart grid; Smart Meters, Real Time Pricing, Advanced metering interface, Internet of vehicles, electric vehicle management, future trends and issues in smart grid

OUTCOMES

Upon completion of this course, the students will able to

- Learn economics of the energy from different sources of generation
- Understand the process and operation of restructured power system, load management
- Explain about load forecasting and configuration of power system appliances

- To gain knowledge on the impact of Solar PV systems.
- Will learn the opportunities and issues in smart grid

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4	H	H	H	L	H	M	H	H	-	M	-	M	H	H	H
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21UPEST2C08 SOLAR ENERGY FOR INDUSTRIAL PROCESS HEAT

OBJECTIVES

- To learn the basic concepts of solar energy related industrial process heat
- To study the techno-economic details for the related process heat industries
- To understand applications of solar industrial process heat
- To describe Industrial Process Issues
- To identify Consequences of pollution

UNIT I INTRODUCTION

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 HEAT

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 HEAT SYSTEM

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

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

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

OUTCOMES

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

- The basic concepts of solar energy-related industrial process heat systems were understood.
- The techno-economic details for the related process heat industries were incorporated.
- Investigate the techno-economic aspects of the associated process heat industries.
- To comprehend solar process industries energy requirements.
- To clarify Industrial Process Issues

- Identifying Waste Consequences

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21UPEST2C09 COMPUTATIONAL FLUID DYNAMICS

OBJECTIVES

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

UNIT I GOVERNING DIFFERENTIAL EQUATIONS AND DISCRETISATION TECHNIQUES

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

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

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

UNIT IV FLOW PROCESSES: FINITE VOLUME METHOD

Discretization of incompressible flow equations – Pressure based algorithms, SIMPLE, SIMPLER & PISO algorithms

UNIT V MODELLING OF COMBUSTION AND TURBULENCE

Mechanisms of combustion and Chemical Kinetics, Overall reactions and intermediate reactions, Reaction rate, Governing equations for combusting flows. Simple Chemical Reacting System (SCRS), Turbulence - Algebraic Models, One equation model & k – ε, k – ω models - Standard and High and Low Reynolds number models.

OUTCOMES

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

- Know the differences between various discretization techniques.
- Learn the finite volume based numerical method for solving diffusion heat transfer problems.
- Learn the finite volume based numerical method for solving convection-diffusion heat transfer problems.
- Understand the discretization of incompressible flow governing equations

- Recognize the impact of various turbulence modelling

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21UPEST2C10 ANALYSIS AND SIMULATION LABORATORY

OBJECTIVES

- To provide a platform to learn and get familiar with computational analysis
- To learn the simulation and analysis software for solving of flow with heat transfer related problems
- To understand the boundary conditions for various problems
- To obtain information on the solver types in Ansys
- To analyze the fluid flow path and temperature distribution in various thermal applications

LIST OF EXPERIMENTS

1. Analysis of the one-dimensional steady state heat diffusion with and without heat generation in a uniformly heated aluminium plate
2. Simulate the two-dimensional steady state heat diffusion in uniformly heated copper plate by applying different boundary condition.
3. Simulation and Analysis of laminar flow through a pipe using Computational Fluid Dynamics
4. Simulation and Analysis of Turbulent Flow in a Pipe using Computational Fluid Dynamics
5. Computational Analysis of Mixing of Hot and Cold Fluid Through a Pipe under steady flow conditions.
6. Two-dimensional Computational Analysis of Steady Compressible Flow in A Convergent – Divergent Nozzle
7. Aerodynamic analysis of two-dimensional steady state incompressible flow Over an Air foil using CFD
8. Computational Analysis of Flow Over an Ahmed Body at specified inlet velocity.
9. Numerical Investigation of 2D air Flow Around a Cylinder using CFD
10. Modelling and Analysis of Transient Heat Transfer in Aluminium Fins using CFD
11. Numerical Simulation and analysis of air flow in an Exhaust manifold using Ansys Fluent.
12. Performance Simulation nitrogen gas Flow through a Porous Media in Catalytic Convertor using CFD
13. Analysis of Combined Natural Convection and Radiation Heat Transfer in a three-dimensional square box on a mesh consisting of hexahedral elements.
14. Simulate and observe Fluid Flow and Heat Transfer in the area of the mixing region of elbow.
15. Analysis of discharge behaviour of a lithium-ion battery (MSMD Battery Model) using CFD

OUTCOMES

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

- Analyze the various parameters influencing the performance of thermodynamic systems
- Learn modelling and measurement tools to solve flow problems related to heat transfer.
- Consider the limits of different issues
- Receive solver style information in Ansys
- Analyze the flow direction and the distribution of the temperature in different heat applications

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21UPEST2C11 ADVANCED POWER PLANT ENGINEERING

OBJECTIVES

- Understand the thermodynamics associated with power plants
- Detail on the role of various utilities in coal based thermal power plants
- Acquire know-how on the working of gas turbine and diesel power plants
- Appreciate the concept of Polygeneration for total energy recovery from a system
- Brief on the working of hydroelectric and nuclear power plants

UNIT I INTRODUCTION

Overview of Indian power sector – load curves for various applications – types of power plants – merits and demerits – criteria for comparison and selection - Economics of power plants.

UNIT II STEAM POWER PLANTS

Basics of typical power plant utilities - Boilers, Nozzles, Turbines, Condensers, Cooling Towers, Water Treatment and Piping system - Rankine Cycle – thermodynamic analysis. Cycle improvements – Superheat, Reheat, Regeneration

UNIT III DIESEL AND GAS TURBINE POWER PLANTS

Engine Cycles - Otto, Diesel & Dual –Theoretical vis-à-vis actual – Typical diesel power plant – Types – Components - Layout - Performance analysis and improvement – Combustion in CI engines - E.C cycles – Gas turbine & Stirling - Gas turbine cycles – thermodynamic analysis – cycle improvements - Intercoolers, Re heaters, regenerators.

UNIT IV ADVANCED POWER CYCLES

Cogeneration systems – topping & bottoming cycles - Performance indices of cogeneration systems – Heat to power ratio - Thermodynamic performance of steam turbine cogeneration systems – gas turbine cogeneration systems – reciprocating IC engines cogeneration systems- Binary Cycle - Combined cycle – IGCC – AFBC / PFBC cycles – Thermionic steam power plant. MHD – Open cycle and closed cycle- Hybrid MHD & steam power plants

UNIT V HYDROELECTRIC & NUCLEAR POWER PLANTS

Hydroelectric Power plants – classifications - essential elements – pumped storage systems – micro and mini hydel power plants General aspects of Nuclear Engineering – Components of nuclear power plants - Nuclear reactors & types – PWR, BWR, CANDU, Gas Cooled, Liquid Metal Cooled and Breeder reactor - nuclear safety – Environmental issue

OUTCOMES

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

- Suggest appropriate power generation technologies for mitigating the energy gap
- Compute the steam rate, heat rate and cost for generating electricity from coal based thermal power plants
- Analyze and suggest measures for improving the performance of gas turbine and diesel power

plants
- Assess the applicability and performance of a cogeneration system
- Identify a suitable type of hydroelectric/nuclear power plant commensurate with the prevailing conditions

REFERENCES

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21UPEST2C12 ADVANCED ENERGY STORAGE TECHNOLOGIES

OBJECTIVES

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

UNIT I INTRODUCTION

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

UNIT II THERMAL STORAGE SYSTEM

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 SYSTEM

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

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

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

OUTCOMES

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

- Identify the energy storage technologies for suitable applications.
- Analyze the energy storage systems using TRNSYS.
- Recognize the concepts and types of batteries.
- Diagnose the principle operations of Hydrogen and Biogas storage.
- Analyze the concepts of Flywheel and compressed energy storage systems

REFERENCES

1. Ibrahim Dincer and Mark A. Rosen, Thermal Energy Storage Systems and Applications, JohnWiley& Sons 2002
2. S.Kalaiselvam and R.Parameshwaran., "Thermal Energy Storage Technologies for Sustainability system Dsesign, assessment and Applications",Elsevier publications(2014)
3. Energy Storage for Sustainable microgrid- David Wenzhong Gao., Elsevier publication (2015).
4. Fuel cell systems Explained, James Larminie and Andrew Dicks, Wiley publications, 2003.
5. Ibrahim, Hussein, Adrian Ilinca, and Jean Perron. "Energy storage systems—Characteristics and comparisons." Renewable and sustainable energy reviews 12, no. 5 (2008): 1221-1250.
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21UPEST2C13 INTERNSHIP

The students may undergo internship training at Research organization / University/ industry for a period as specified in the curriculum during summer vacation. In this case the training has to be undergone continuously for the entire period.

Duration of Internship	Credits
2 Weeks to 4 weeks	2

At the end of internship, the student shall submit a report. The Viva-Voce Examination will be conducted by a three-member committee constituted by the Head of the Department. The committee comprises of one expert from an industry/organization and two members (co-ordinator and supervisor) from the Department. Certificates (issued by the Organization) submitted by the student shall be attached to the mark list and sent to Controller of Examinations by the Head of the Department.

INTERNSHIP TRAINING

EVALUATION

Report	Presentation	Viva Voce	Total
40	30	30	100

21UPEST2C14 PROJECT WORK PHASE I

OBJECTIVES

- A research project topic may be selected either from published lists or from the creative ideas of the students themselves in consultation with their project supervisor.

EVALUATION

- Project work evaluation is based on Regulations of Credit system University Departments Post graduate programs of Periyar University

OUTCOME

- The students would apply the knowledge gained from theoretical and practical courses in solving problems, so as to give confidence to the students to be creative, well planned, organized, coordinated in their project work phase – II.

21UPEST2C15 NANOMATERIALS FOR ENERGY APPLICATIONS

OBJECTIVES

- To foundational knowledge of Nanoscience and related fields.
- To make the students acquire an understanding the Nanoscience and Applications
- To help them understand the broad outline of Nanoscience and Nanotechnology.
- To understand the classification of nanostructured materials.
- To understand the characterization of nanomaterials

UNIT I BASICS AND SCALE OF NANOTECHNOLOGY

History of Nanomaterial Development - Importance of Nanomaterials - Potential Problems of Nanomaterials

UNIT II PRINCIPLES, METHODS, FORMATION MECHANISMS, AND STRUCTURES OF NANOMATERIALS

Principles of Physical Vapor Deposition – Chemical Vapor Deposition - Filtered Cathodic Vacuum Arc Deposition - Comparison of Various Vapor Deposition Methods – Precipitation – Sol- Gel Method - Chemical-Reduction Method - Comparison of Various Liquid Nanoparticle Preparation Methods - Mechanical Alloying - Nanomaterial Preparation via Solid-Phase Methods - Microstructures and Defects in Body Nanomaterials

UNIT III PROPERTIES OF NANOMATERIALS

Elasticity of Nanomaterials - Strengths, Hardnesses and Hall-Petch Relationships in Nanomaterials – Nanomaterial Fracture and Fatigue - Nanomaterial Creep and Super plasticity - Deformation and Fracture Mechanisms in Nanomaterials - Melting Point - Thermal Conductivity- Specific Heat- Thermal Expansion.

UNIT IV SYNTHESIS OF NANOMATERIALS

Ball milling – Inert gas condensation technique (IGCT)–Thermal evaporation–Pulsed laser deposition (PLD)–DC/RF magnetron sputtering – Molecular beam epitaxy (MBE)–Melt spinning process –IC Fabrication process– Microlithography– Etching – Wet cleaning– CMP–Backend process – Atomic layer deposition (ALD)

UNIT V CHARACTERIZATION OF NANOSTRUCTURES

Characterization: X-ray diffraction -Fourier transform infrared spectroscopy- Photoluminescence spectroscopy –Ultraviolet spectroscopy (UV)- Photoluminescence Spectroscopy (PL)- Nuclear Magnetic Resonance spectroscopy (NMR) -Atomic force Microscope (AFM) -Differential thermal analysis (DTA) -Field emission scanning electron microscopy (FESEM) and environmental scanning electron microscopy (ESEM)- High resolution transmission electron microscope (HRTEM)-X-ray photoelectron spectroscopy (XPS)

OUTCOMES

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

- After completing this course students will be able to:

- Learn about the background on Nanoscience
- Understand the synthesis of nanomaterials and their application and the impact of nanomaterials on environment
- Apply their learned knowledge to develop Nanomaterial's.
- Design a nanomaterial for a complex engineering system where nanoscale properties are of importance

REFERENCES

1. T. Pradeep, "A Textbook of Nanoscience and Nanotechnology", Tata McGraw Hill Education Pvt. Ltd.2012
2. Hari Singh Nalwa, "Nanostructured Materials and Nanotechnology", Academic Press, 2008
3. "Nanocrystals: Synthesis, Properties and Applications", C. N. R. Rao, P. J. Thomas and G. U. Kulkarni, Springer (2007).
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21UPEST2C16 PROJECT WORK PHASE II

OBJECTIVES

- The objective of the research project work is to produce factual results of their applied research idea in the thermal Engineering, from phase – I.

EVALUATION

Project work evaluation is based on Regulations of Credit system University Departments - Post graduate programs of Periyar University

OUTCOME

- The students would apply the knowledge gained from theoretical and practical courses in solving problems, so as to give confidence to the students to be creative, well planned, organized, coordinated project outcome of the aimed work.

PROFESSIONAL ELECTIVES

21UPEST2E01 SOLAR ENERGY TECHNOLOGIES

OBJECTIVES

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

UNIT I SOLAR RADIATION AND COLLECTORS

Solar angles – Sun path diagrams – Radiation - extra-terrestrial 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

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

UNIT III SOLAR PV FUNDAMENTALS

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

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 - stand-alone - 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

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

OUTCOMES

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

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

REFERENCES

1. Goswami, D.Y., Kreider, J. F. and & Francis., Principles of Solar Engineering, Taylor and Francis, 2000
2. Chetan Singh Solanki, Solar Photovoltatics – Fundamentals, Technologies and Applications, PHI Learning Private limited 2011
3. Sukhatme S P, J K Nayak, Solar Energy – Principle of Thermal Storage and collection, Tata McGraw Hill, 2008.
4. Solar Energy International, Photovoltaic – Design and Installation Manual – New Society Publishers, 2006
5. Roger Messenger and Jerry Vnetre, Photovoltaic Systems Engineering, CRC Press, 2010.

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21UPEST2E02 NUCLEAR ENERGY TECHNOLOGY

OBJECTIVES

- To understand the main aspects of Nuclear Engineering and history of nuclear energy
- Describes the interaction of radiation with matter and nuclear reactions
- To familiarize in nuclear fission and the chain reaction
- Introduction to nuclear reactor theory and heat removal from nuclear reactors
- To impart the knowledge of waste disposal and radiation protection

UNIT I BASIC NUCLEAR CONCEPTS

Atomic Structure, Nuclear models, Equivalence of mass and energy, binding energy, Radio activity, halflife, mechanism of nuclear fission and fusion, decay chains, critical mass and composition, neutron reactions.

UNIT II NUCLEAR FUELS

Nuclear fuel reserves of Uranium and Thorium, Nuclear fuel cycles, characteristics, production and purification, other fuels Zirconium, Beryllium, Reprocessing of nuclear fuels, Thorium

UNIT III NUCLEAR REACTORS

Nuclear reactors and classification, boiling water reactors (BWR), pressurized heavy water reactor (PHWR), fast breeder reactor (FBR), basics of nuclear fusion reactor.

UNIT IV NUCLEAR POWER PLANT -WASTE MANAGEMENT AND SAFETY

Nuclear Power Plant, Nuclear power plant safety systems, Nuclear Accidents- consequences– case study, criteria for safety, Nuclear Waste management, International Convention on safety aspects, radiation hazards and their prevention.

UNIT V NUCLEAR RADIATION APPLICATIONS

Radiation processing of food and allied products, applications of radio isotopes in Industry and Agriculture, Industrial radiotracer applications in Ground water exploration, Desalination

OUTCOMES

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

- At the end of the module the students are able to understand: how nuclear energy is produced today
- The physical principles in which the production of nuclear energy is based how nuclear power systems work
- Basic concepts of radiation and radiation protection
- The basis of nuclear safety, The economic, issues and prospects of nuclear power today

REFERENCES

1. Fundamentals of Nuclear Engineering by TJ Cannoly, John Wiley.
2. Introduction to Nuclear Reactor Theory by JR Lamarsh, Wesley.
3. Introduction to Nuclear Power by JG Collier and GF Hewitt, Hemisphere Publishing, New York.
4. Nuclear Reactor Engineering by S Glasstone and A Sesonske, Von Nostrand.

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21UPEST2E03 POWER ELECTRONICS FOR RENEWABLE ENERGY SYSTEMS

OBJECTIVES

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

UNIT I INTRODUCTION

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

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

UNIT III POWER CONVERTERS

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

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

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

OUTCOMES

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

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

REFERENCES

1. Rashid.M. H “power electronics Hand book”, Academic press, 2007.
2. Leon Freris, David Infield, “Renewable energy in power systems”, John Wiley & Sons, 2008.
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.

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3	H	H	H	M	H	L	H	-	-	-	-	L	M	L	L
4	L	M	L	L	M	L	M	-	-	-	-	-	M	L	L
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21UPEST2E04 ENVIRONMENTAL ENGINEERING AND POLLUTION CONTROL

OBJECTIVES

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

UNIT I INTRODUCTION

Man & Environment – Types of Pollution – Global Environmental issues – Environmental Impact Assessment – Global Warming Issues –CO2 Mitigation – Basic definition of Pollution Indicators – Noise Pollution

UNIT II WATER POLLUTION

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

UNIT III AIR POLLUTION

Sources – Ambient Air Quality Standards – Emission Limits – Equipment for Ambient Air & Stack Monitoring – Principles of operation of Particulate Control Equipment (ESPs, Bag Filters, Cyclone Separators etc.,) – Vehicular Pollution and its Control.

UNIT IV SOLID & HAZARDOUS WASTE MANAGEMEN

Types & Sources – Types (Municipal, Biomedical, Industrial, Hazardous etc.,) – Waste Generation – Composition – Physical / Chemical / Biological Properties – Transformation Technologies for Waste Treatment – Landfill Management – Leachate Generation – e Waste Disposal

UNIT V GLOBAL WARMING & CLIMATE CHANGE

Impact of Global Warming / Climate Change on various sectors – Green House Gases & Effect– Carbon Cycle – CDM – Carbon Trading – Carbon Sequestration – Carbon Capture & Storage– UNFCCC – IPCC Protocols

OUTCOMES

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

- Types and effects of each type of pollution on man – earth will be made known.
- Technical aspects of Global Warming will make them understand the impact they have on climate
- Technologies that are available for reduction of pollutants dumped into the atmosphere
- Cursory / superficial formation - the students – had in Hazardous waste, waste disposal hitherto will be deep & sensible enough after studying this subject
- Comprehend the different techniques available for safe disposal of hazardous waste

REFERENCES

1. C. S. Rao, Environmental Pollution Control Engineering, New Age International Publishers, 2006
2. Peavy, H.S. and D.R. Rowe, G.Tchobanoglous: Environmental Engineering – McGraw Hill Book Company, New York, 1985
3. G. Masters: Introduction to Environmental Engineering and Science, Prentice Hall of India Pvt Ltd, New Delhi, 2003
4. Ludwig, H. W.Evans: Manual of Environmental Technology in Developing Countries, International Book Company, Absecon Highlands, N.J, 1991
5. Arcadio P Sincero and G. A. Sincero, Environmental Engineering – A Design approach, Prentice Hall of India Pvt Ltd, New Delhi, 2002

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21UPEST2E05 WIND ENERGY CONVERSION SYSTEMS

OBJECTIVES

- To understand the basic components of wind energy conversion system and control the wind power.
- Knowledge to design the wind turbine (HAWT & VAWT),
- Design of fixed and variable speed wind turbine
- Modeling the grid connected WECS system studies
- Methods of Storage of wind energy

UNITI MEASUREMENT AND INSTRUMENTATION

Instrumentation – Beau fort number -Gust parameters – wind type – power law index -Betz constant -Terrain value.

UNIT II WINDMILL STRUCTURES AND STANDARDS

Energy in wind– study of wind applicable Indian standards – Steel Tables, Structural Engineering- Wind turbine aerodynamics, momentum theories, basic aerodynamics, airfoils and their characteristics.

UNIT III VARIABLES IN WIND ENERGY CONVERSION SYSTEMS

Variables in wind energy conversion systems – wind power density – power in a wind stream– wind turbine efficiency – Forces on the blades of a propeller – Solidity and selection curves.

UNIT IV WIND TURBINES AND CHARACTERISTICS

HAWT, VAWT– tower design-power duration curves- wind rose diagrams- study of characteristics - actuator theory- controls and instrumentations – Blade Element Theory-, number of blades, blade profile, 2/3 blades and teetering, coning, power regulation, yaw system, tower. Wind turbine loads, aerodynamic loads in steady operation, wind turbulence, static - dynamic - fatigue analysis

UNIT V WIND ENERGY STORAGE

Grid-combination of diesel generator, Battery storage – wind turbine circuits- Wind farms—fatigue stress – Hybrid Systems - Annual Energy Output (AEO). Synchronous and asynchronous generators and loads, integration of wind energy converters to electrical networks, inverters. Testing of WECS. Noise. Miscellaneous topics

OUTCOMES

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

- Aptitude & proficiency in grid interconnection requirements for wind farms.
- Ability of integrating power electronics device with Renewable Energy Sources.
- Know-how of Wind Power Control.
- Skill in developing MPPT techniques.
- To know Wind energy storage methods

REFERENCES

1. Burton, T et.al, (2011) Wind Energy Handbook, 2nd Edition, John Wiley and Sons
2. Manwell, J.F. et.al, (2009) Wind Energy Explained, 2nd Edition, John Wiley and Sons
3. Spera, D. A. (2009) Wind Turbine Technology: Fundamental concepts of Wind Turbine Engineering, 2nd Edition, ASME Press
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21UPEST2E06 ELECTRICAL DRIVES AND CONTROLS

OBJECTIVES

- To expose students to the operation, application and control of power conversion systems employing electric drive to cater to industrial needs.
- To familiarize the operation principles, and design of starting, braking, and speed control arrangements for electric motors and their applications
- To provide strong foundation to assess performance of different industrial drives
- To Design new control and power conversion schemes
- To justify and implementing alternative solutions considering the critical and contemporary issues

UNIT I REVIEW OF CONVENTIONAL MOTOR DRIVES

Characteristics of DC and AC motors for various applications — starting and speed control — methods of breaking.

UNIT II PHYSICAL PHENOMENA IN ELECTRICAL MACHINES

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

UNIT III INTRODUCTION TO SOLID STATE POWER CONTROLLERS

Power devices - Triggering Circuits - Rectifiers - Choppers. Invertors - AC Controllers

UNIT IV SUPERCONDUCTIVITY

Super conducting generators — motors and magnets — Super conducting magnetic energy storage (SMES).

UNIT V SOLID STATE MOTOR CONTROLLERS

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

OUTCOME

- Examine various applications in industrial and domestic areas where use of electric drives are essential.
- Classify types of electric drives systems based on nature of loads, control objectives, performance and reliability.
- Combine concepts of previously learnt courses such as, electrical machines, Control and power electronics to cater to the need of automations in industries.
- Select most suitable type and specification of motor drive combination for efficient conversion and control of electric power.
- Identify the critical areas in application levels, and derive typical solutions.

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2. Fundamental of Electrical Drives, G.K. Dubey, New Age International Publication
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21UPEST2E07 FUEL AND COMBUSTION

OBJECTIVES

- To detail on the types of biofuel, its surplus availability and characteristics.
- To impart knowledge on stoichiometry and combustion of bio fuels
- To provide insight to the possibilities of producing liquid fuels
- To impart knowledge on fossil fuel and their combustion characteristics.
- To make students inquisitive about the problems of combustion

UNIT I BASICS OF FUELS

Modern concepts of fuel, Solid, liquid and gaseous fuels, composition, basic understanding of various properties of solid fuels - heating value, ultimate analysis, proximate analysis, ash deformation points; liquid fuels - heating value, density, specific gravity, viscosity, flash point, ignition point (self, forced), pour point, ash composition and gaseous fuels.

UNIT II PETROLEUM AS A SOURCE OF ENERGY

Origin, composition, classification of petroleum, grading of petroleum; Processing of petroleum: Distillation of crude petroleum, petroleum products, purification of petroleum products – thermal processes, catalytic processes, specifications and characteristics of petroleum products.

UNIT III NATURAL GAS AND ITS DERIVATIVES

Classification of gaseous fuels – natural gas and synthetic gases, Natural gas reserves - World and India, properties of natural gas – heating value, composition and density

UNIT IV PRINCIPLES OF COMBUSTION

Chemistry and Stoichiometric calculation, thermodynamic analysis and concept of adiabatic flame temperature; Combustion appliances for solid, liquid and gaseous fuels: working, design principles and performance analysis.

UNIT V EMISSIONS FROM FUEL COMBUSTION SYSTEMS

Pollutants and their generation, allowed emissions, strategies for emission reduction, Euro and BIS norms for emission, recent protocols

OUTCOMES

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

- To understand the fuel combustion process
- Design a biogas plant for a variety of biofuels
- Determine and compare the cost of steam generation from biofuels with that of coal and petroleum fuels
- Apply fundamental aspects of combustion related problem and an understanding on the combustion appliances.
- Synthesize liquid biofuels for power generation from biomass

REFERENCES

1. David Boyles, Bio Energy Technology Thermodynamics and costs, Ellis Hoknood Chichester, 1984.
2. Fuels & Combustion by Sharma S.P. & Chander Mohan, Tata McGraw Hill Publishing Co. Ltd.
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21UPEST2E08 PRINCIPLES AND APPLICATIONS OF HYDROGEN STORAGE

OBJECTIVES

- To impart knowledge on use of hydrogen for achieving sustainable growth
- To facilitate analysis of the challenges in transition to hydrogen economy
- To understand and demonstrate the hydrogen production technologies, storage methods and strategies for transition to hydrogen economy
- To know the concepts and characteristics of various types of fuel
- To know the application of fuel cells with economic and environment analysis

UNITI INTRODUCTION

History of hydrogen – origin of hydrogen emission – molecular hydrogen – hydrogen in engineering – hydrogen bond – photosynthesis – bio hydrogen.

UNIT II THERMODYNAMICS

Gibbs Phase Rule; Pressure-Composition-Temperature plots; Van't Hoff plots for absorption desorption enthalpies; Gravimetric capacities; Hysteresis in cycling; Joule-Thomson Effect, Non-ideal treatment of hydrogen gas

UNIT III HYDROGEN PRODUCTION

Semiconductor catalyst – water splitting and nano technology – steam reforming – partial oxidation – electrolysis – thermolysis

UNIT IV DESIGN AND APPLICATIONS OF STORAGE SYSTEMS

Conventional methods of hydrogen storage – solid state; metal organic – Zeolites – carbons – interstitial hydrides – AB5 & AB2 compound

UNIT V HYDROGEN FUEL CELL

Hydrogen fuel cell design – proton exchange membrane fuel cells – preparation of nafion membrane - catalyst

OUTCOMES

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

- Upon successful completion of the course, the student will be able to
- Evaluate the performance of fuel cells under different operating conditions.
- Select and defend appropriate fuel cell technology for a given application.
- Design and develop suitable hydrogen storage system to be used along with fuel cell system.
- Minimize environmental hazards associated with the use of hydrogen storage and fuel cell

REFERENCES

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2. Angelo Basile, Adolfo Iulianelli, Advances in Hydrogen Production, Storage and Distribution, 1st Edition, Woodhead Publishers, Cambridge (UK), 2014.
3. Gavrilyuk, Hydrogen Energy for Beginners, Pan Sanford Publication private ltd. UK
4. Michael Hirscher, Hand Book of Hydrogen Storage, 1st Edition, Wiley-VCN Verlag GmbH, 2010.
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21UPEST2E09 WASTE MANAGEMENT AND ENERGY RECOVERY TECHNIQUES

OBJECTIVES

- To provide information on various methods of waste management
- To familiarize students with recent energy generation techniques
- To detail on the recent technologies of waste disposal
- To know about the disposal of hazardous wastes.
- To make student realize on the importance of healthy environment

UNIT I CHARACTERISTICS AND PERSPECTIVES

Sources – Types – Composition – Generation – Estimation Techniques – Characterization – Types of Collection System – Transfer Stations – Transfer Operations – Material Recycle / Recovery Facilities

UNIT II UNIT OPERATIONS & TRANSFORMATION TECHNOLOGIES

Separation & Processing: Size Reduction – Separation through Density Variation, Magnetic / Electric Field: Densification - Physical, Chemical and Biological Properties and Transformation Technologies – Selection of Proper Mix of Technologies

UNIT III WASTE DISPOSAL

Landfill Classification – Types – Siting Considerations – Landfill Gas (Generation, Extraction, Gas Usage Techniques) – Leachates Formation, Movement, Control Techniques – Environmental Quality Monitoring – Layout, Closure & Post Closure Operation – Reclamation

UNIT IV TRANSFORMATION TECHNOLOGIES AND VALUE ADDITION

Physical Transformation: Component Separation & Volume Reduction: Chemical Transformation – Combustion / Gasification / Pyrolysis: Energy Recovery - Biological Transformation – Aerobic Composting – Anaerobic Digestion

UNIT V HAZARDOUS WASTE MANAGEMENT & WASTE RECYCLING

Definition – Sources – Classification – Incineration Technology - Incineration vs Combustion Technology – RDF / Mass Firing – Material Recycling: Paper / Glass / Plastics etc., - Disposal of White Goods & E-Wastes

OUTCOMES

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

- Waste characterization, Segregation, Disposal will be made known
- Technologies that are available for effective waste disposal along with pros / cons will become cleaner to students
- Able to convert waste into useful energy.
- First-hand information on present day waste related problems (Hazardous Waste, Pharma Waste, Biomedical Waste etc).

- Get awareness on the healthy environment.

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21UPEST2E10 DESIGN AND ANALYSIS OF TURBOMACHINES

OBJECTIVES

- To understand the energy transfer process in turbo machines and to derive governing equations
- To understand the functional aspects and performance of turbo machines
- To learn about the components of combustion chamber and their functions
- To understand the working and performance of turbines
- To calculate the performance of gas turbines and jet engines

UNIT I INTRODUCTION

Basics of isentropic flow – static and stagnation properties – diffuser and nozzle configurations area ratio – mass flow rate – critical properties. Energy transfer between fluid and rotor velocity triangles for a generalized turbo machines - velocity diagrams. Euler's equation for turbo machines and its different forms. Degree of reaction in turbo-machines – various efficiencies – isentropic, mechanical, thermal, overall and polytrophic

UNIT II CENTRIFUGAL AND AXIAL FLOW COMPRESSORS

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

UNIT III COMBUSTION CHAMBER

Basics of combustion - Structure and working of combustion chamber – combustion chamber arrangements - flame stability – fuel injection nozzles. Flame stabilization - cooling of combustion chamber.

UNIT IV AXIAL AND RADIAL FLOW TURBINES

Elementary theory of axial flow turbines - stage parameters- multi-staging - stage loading and flow coefficients. Degree of reaction - stage temperature and pressure ratios – single and twin spool arrangements – performance - Matching of components - Blade Cooling - Radial flow turbines.

UNIT V GAS TURBINE AND JET ENGINE CYCLES

Gas turbine cycle analysis – simple and actual - Reheated, Regenerative and Intercooled cycles for power plants. Working of Turbojet, Turbofan, Turboprop, Ramjet, Scramjet and Pulsejet Engines and cycle analysis – thrust, specific impulse, specific fuel consumption, thermal and propulsive efficiencies.

OUTCOMES

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

- Analyze the energy transfer process in thermodynamic systems
- Calculate the performance of centrifugal flow and axial flow combustion systems
- Design and analyze the combustion chamber for turbomachines

- Compute and analyze the performance of axial and radial flow turbines
- Predict the performance of gas turbines and thermodynamic energy systems

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3. Cohen, H., Rogers, G F C and Saravanmotto, H I H, Gas Turbine Theory, John Wiley, 5th Edition 2001.
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21UPEST2E11 MODELLING AND ANALYSIS OF ENERGY SYSTEMS

OBJECTIVES

- To learn to apply mass and energy balances for the energy systems
- To learn the modeling and simulation techniques for energy systems.
- To learn the optimization techniques to optimize the energy system.
- To learn to use the energy-economy models.
- To understand the application of case studies.

UNIT I INTRODUCTION

Primary energy analysis - energy balance for closed and control volume systems - applications of energy analysis for selected energy system design - modelling overview - levels and steps in model development - Examples of models – curve fitting and regression analysis

UNIT II MODELLING AND SYSTEMS SIMULATION

Modelling of energy systems – heat exchanger - solar collectors – distillation -rectification turbo machinery components - refrigeration systems - information flow diagram - solution of set of non-linear algebraic equations - successive substitution - Newton Raphson method- examples of energy systems simulation

UNIT III OPTIMISATION TECHNIQUES

Objectives - constraints, problem formulation - unconstrained problems - necessary and sufficiency conditions. Constrained optimization - Lagrange multipliers, constrained variations, Linear Programming - Simplex tableau, pivoting, sensitivity analysis - New generation optimization techniques – Genetic algorithm and simulated annealing – examples.

UNIT IV ENERGY- ECONOMY MODELS

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

UNIT V APPLICATIONS AND CASE STUDIES

Case studies of optimization in Energy systems problems- Dealing with uncertainty- probabilistic techniques – Trade-offs between capital and energy using Pinch analysis

OUTCOMES

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

- Apply mass and energy balances for the energy systems
- Do Simulation and Modeling of typical energy system
- Use the optimization techniques to optimize the energy system.
- Perform Energy-Economic Analysis for the typical applications
- Have knowledge in optimization of Energy systems problems

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2. Bejan, A, Tsatsaronis, G and Moran, M., Thermal Design and Optimization, John Wiley & Sons 1996
3. Stoecker, W.F., Design of Thermal Systems, McGraw Hill, 2011.
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5. Yogesh Jaluria, Design and Optimization of Thermal Systems, CRC Press INC, 2008
6. C. Balaji, Essentials of Thermal System Design and Optimization, Ane Books, 2011

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21UPEST2E12 COGENERATION AND WASTE HEAT RECOVERY SYSTEMS

OBJECTIVES

- To gain fundamental knowledge in energy generation, heat transfer in thermal engineering.
- To reduce the impact global warming for betterment of living things to serve healthy life.
- To knowledge on recovery of waste heat recovery
- To know the impact on environmental of waste heat recovery
- To identify the techniques on waste heat recovery

UNIT I COGENERATION

Introduction - Principles of Thermodynamics - Combined Cycles - Topping – Bottoming - Organic Rankine Cycles - Advantages of Cogeneration Technology

UNIT II APPLICATION & TECHNO ECONOMICS OF COGENERATION

Cogeneration Application in various Industries like Cement, Sugar Mill, Paper Mill etc. Sizing of Waste Heat Boilers - Performance Calculations - Part Load Characteristics. Selection of Cogeneration Technologies - Financial Considerations-Operating and Investments - Costs of Cogeneration.

UNIT III WASTE HEAT RECOVERY

Introduction - Principles of Thermodynamics and Second Law - Sources of Waste Heat Recovery - Diesel Engines and Power Plant etc.

UNIT IV WASTE HEAT RECOVERY SYSTEMS, APPLICATIONS & TECHNO ECONOMICS

Recuperators - Regenerators - Economizers - Plate Heat Exchangers - Waste Heat Boilers - Classification, Location, Service Conditions, Design Considerations, Unfired Combined Cycle - Supplementary Fired Combined Cycle - Fired Combined Cycle. Applications in Industries - Fluidized Bed Heat Exchangers - Heat Pipe Exchangers - Heat Pumps - Thermic Fluid Heaters Selection of Waste Heat Recovery Technologies - Financial Considerations - Operations and Investment Costs of Waste Heat Recovery.

UNIT V ENVIRONMENTAL CONSIDERATIONS

Environmental considerations for Cogeneration and Waste Heat Recovery – Pollution

OUTCOMES

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

- The students will acquire fundamental knowledge in energy generation,
- Understand heat transfer in thermal engineering.
- Students will get the ability solve problems using mathematical concepts and to use modern engineering tools, software and equipment
- To analyze and solve complex engineering problems.
- The students will be able to solve real world problems and reduce the impact global warming for

betterment of living things to serve healthy life.

REFERENCES

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21UPEST2E13 FLUIDIZED BED SYSTEMS

OBJECTIVES

- To understand the behavior of fluidized beds
- To learn about the heat transfer process
- To differentiate the combustion and gasification, and appreciate the relative merits
- To design components of fluidized bed systems
- To understand the industrial applications of fluidized bed systems

UNIT I FLUIDIZED BED BEHAVIOUR

Characterization of bed particles - comparison of different methods of gas - solid contacts. Fluidization phenomena - regimes of fluidization – bed pressure drop curve. Two phase and well-mixed theory of fluidization. Particle entrainment and elutriation – unique features of circulating fluidized beds

UNIT II HEAT TRANSFER

Different modes of heat transfer in fluidized bed – bed to wall heat transfer – gas to solid heat transfer – radiant heat transfer – heat transfer to immersed surfaces. Methods for improvement – external heat exchangers – heat transfer and part load operations

UNIT III COMBUSTION AND GASIFICATION

Fluidized bed combustion and gasification – stages of combustion of particles – performance - start- up methods. Pressurized fluidized beds

UNIT IV DESIGN CONSIDERATIONS

Design of distributors – stoichiometric calculations – heat and mass balance – furnace design of heating surfaces – gas solid separators.

UNIT V INDUSTRIAL APPLICATIONS

Physical operations like transportation, mixing of fine powders, heat exchange, coating, drying and sizing. Cracking and reforming of hydrocarbons, carbonization, combustion and gasification. Sulphur retention and oxides of nitrogen emission Control.

OUTCOMES

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

- Calculate the behavior of fluidized beds
- Analyze the heat transfer process in fluidized beds
- Apply concepts of combustion and gasification in fluidized beds
- Design fluidized beds for given applications
- Apply fluidized bed systems for various industrial applications

REFERENCES

1. Fabrizio Scala, Fluidized Bed Technologies for Near-Zero Emission Combustion and Gasification, 2013
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21UPEST2E14 HYDRO POWER SYSTEMS

OBJECTIVES

- To understand the process of generation of hydropower, its potential & energy extraction.
- To provide knowledge of planning, design and development of hydroelectric power plants
- To understand the aerodynamic principle of turbine blade design.
- To understand the recent developments and technologies in the wind & hydro energy
- To know about the operation and maintenance of civil engineering works

UNIT I INTRODUCTION

Overview of Hydropower Systems — Preliminary Investigation — Determination Requirements — Preparation of Reports and Estimates — Review of World Resource Cost of Hydroelectric Power — Basic Factors in Economic Analysis of Hydropower Projects — Project Feasibility — Load Prediction and Planned Development.

UNIT II DEVELOPMENT OF PROTOTYPE SYSTEMS

Advances in Planning, Design and Construction of Hydroelectric Power Stations — Trends Development of Generating Plant and Machinery — Plant Equipment for Pumped Store Schemes — Some aspects of Management and Operation — Uprating and Refurbishing of turbines.

UNIT III POWER STATION OPERATION AND MAINTENANCE

Governing of Water Turbines - Function of Turbine Governor - Condition for Governing stability - Surge Tank Oscillation and Speed Regulative Problem of Turbine Governing Future.

UNIT IV RESERVOIRS

Problem of Management - Maintenance of Civil Engineering Works - Maintenance of electrical Engineering Works.

UNIT V INFORMATION TECHNOLOGY IN HYDRO POWER SYSTEMS

Development of Software. Computer Aided Hydropower System Analysis - Design - Execution - Testing - Operation and Control and Monitoring of Hydropower Services.

OUTCOMES

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

- Understand the hydrodynamics of open-channel flows.
- Understand the hydraulic design/sizing of the main components of a Hydro power Plant
- Compute steady-state profiles of open-channel flows with variable geometry and discharge.
- Carry out the main hydrological analyses necessary for the design of hydroelectric systems and simulation of their productivity
- Estimate the hydrological alterations induced by the presence of hydroelectric power stations.

REFERENCES

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3. Tyler G. Hicks (1988), Power Plant Evaluation and Design

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21UPEST2E15 SMART GRID TECHNOLOGIES

OBJECTIVES

- To understand concept of smart grid and developments on smart grid.
- To understand smart grid technologies and application of smart grid concept in hybrid
- electric vehicles etc.
- To have Knowledge on smart substations, feeder automation and application for
- monitoring and protection.
- To have knowledge on micro grids and distributed energy systems.
- To know power quality aspects in smart grid.

UNIT I INTRODUCTION TO SMART GRID

Evolution of electric grid- Concept of smart grid - Definitions – Need of smart grid- Functions of smart grid – Opportunities & barrier of smart grid- Difference between conventional & smart grid- Concept of resilient & self-healing grid present development & international policies on smart grid – case study of smart grid.

UNIT II SMART GRID TECHNOLOGIES

Introduction to smart meters- Real time prizing – Smart appliances- Automatic meter reading (AMR)- Outage management systems (OMS)- plug in hybrid electric vehicles (PHEV)-Vehicle to grid- Smart sensors- Home & building automation.

UNIT III SMART GRID TECHNOLOGIES

Smart Substations – Substation automation – Feeder automation – Intelligent electronic devices (IED) & their application for monitoring protection – Smart storage like battery – SMES- Pumped hydro – Compressed air energy storage – Wide area measurement system (WAMS)-Phasor measurement unit (PMU).

UNIT IV MICRO GRIDS AND DISTRIBUTED ENERGY RESOURCES

Concept of micro grid- Need & applications of micro grid- Formation of micro grid- Issues of interconnection – Protection & control of micro grid- Plastic & organic solar cells- Thin film solar cells – Variable speed wind generators- Fuel cells- Micro turbines- Captive power plants- Integration of renewable energy sources.

UNIT V INFORMATION AND COMMUNICATION TECHNOLOGY FOR SMART GRID

Advanced metering infrastructure (AMI)- Home area network (HAN)- Neighborhood area Network (NAN)-Wide area network (WAN).

OUTCOMES

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

- Understand smart grids and analyze grid policies and development in smart grids.
- Develop concepts of smart grid technologies in hybrid electrical vehicles etc.
- Understand smart substation, feeder automation, GIS etc.

- Analyze micro grids and distributed generation systems.
- Analyze the effect of power quality in smart grid and to understand latest developments in ICT for smart grid

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2. "Integration of Green and Renewable Enegry in Electric Power Systems", Ali Keyhani,
3. Mohammad N. Marwail, Min Dai Wiley.
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6. "Smart Grids", Jean Clude Sabonnadiere, Nouredine Hadjsaid, Wiley Blackwell.
7. "Smart Power: Climate Changes the Smart Grid, and the Future of Electric Utilities", Peter S. Fox Penner, Island Press; 1 edition 8 Jun 2010
8. "Microgrids and Active Distribution Networks." S. Chowdhury, S.P. Chowdhury, P.Crossley , Institution of Engineering and Technology, 30 Jun 2009

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21UPEST2E16 SOLAR REFRIGERATION AND AIRCONDITIONING

OBJECTIVES

- To understand the fundamentals of solar air conditioning and refrigeration.
- Acquire the knowledge of psychometrics, cooling and heat load calculations, air distribution systems, duct design, vapor compression and absorption systems
- The course will build upon the fundamentals of thermodynamics
- Introduce elements of basic RAC machinery and its operating principles and design issues
- Study of the various equipment-operating principles, operating and safety controls employed in refrigeration air conditioning systems

UNIT I INTRODUCTION

Potential and scope of solar cooling. Types of solar cooling systems, solar collectors and storage systems for solar refrigeration and air-conditioning.

UNIT II REFRIGERATION CYCLES

Solar operation of vapor absorption and compression refrigeration cycles and their assessment.

UNIT III THERMAL MODELLING

Thermal modelling and computer simulation for continuous and intermittent solar refrigeration and air conditioning systems.

UNIT IV SOLAR COOLING SYSTEMS

Solar desiccant cooling systems. Open cycle absorption/ desorption solar cooling alternatives. Advanced solar cooling systems. Refrigerant storage for solar absorption cooling systems.

UNIT V ECONOMICS

Solar thermoelectric refrigeration and air-conditioning. Solar economics of cooling systems and Control and Monitoring of Hydropower Services.

OUTCOMES

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

- Illustrate the fundamental principles and applications of refrigeration and air conditioning system
- Obtain cooling capacity and coefficient of performance by conducting test on vapour compression refrigeration systems
- Present the properties, applications and environmental issues of different refrigerants
- Calculate cooling load for air conditioning systems used for various
- Operate and analyze the refrigeration and air conditioning systems

REFERENCES

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3. Ursula Eicker, (2009) Low Energy Cooling for Sustainable Buildings, John Wiley and Sons
4. Hans-Martin Henning, (2007) Solar-assisted air conditioning in buildings: a handbook for planners, Springer
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6. Sayigh, A. A. M., McVeigh, J. C. (1992) Solar air conditioning and refrigeration, Pergamon Press

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21UPEST2E17 INNOVATION AND ENTREPRENEURSHIP

OBJECTIVES

- To understand the Entrepreneurial Opportunities in current scenario
- To learn various Entrepreneurial Process and Decision Making
- Acquire Knowledge in Crafting business models and Lean Start-ups
- To inculcate ideas in Organizing Business and Entrepreneurial Finance
- To develop and explore business opportunities

UNIT-I INTRODUCTION TO ENTREPRENEURSHIP

Entrepreneurs; entrepreneurial personality and intentions - characteristics, traits and behavioral; entrepreneurial challenges.

UNIT-II ENTREPRENEURIAL OPPORTUNITIES

Opportunities. Discovery / creation, Pattern identification and recognition for venture creation: prototype and exemplar model, reverse engineering.

UNIT-III ENTREPRENEURIAL PROCESS AND DECISION MAKING

Entrepreneurial ecosystem, Ideation, development and exploitation of opportunities; Negotiation, decision making process and approaches, Effectuation and Causation.

UNIT-IV CRAFTING BUSINESS MODELS AND LEAN START-UPS

Introduction to business models; Creating value propositions-conventional industry logic, value innovation logic; customer focused innovation; building and analyzing business models; Business model canvas, Introduction to lean startups, Business Pitching.

UNIT-V ORGANIZING BUSINESS AND ENTREPRENEURIAL FINANCE

Forms of business organizations; organizational structures; Evolution of Organization, sources and selection of venture finance options and its managerial implications. Policy Initiatives and focus; role of institutions in promoting entrepreneurship

OUTCOMES

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

- Comprehend the role of bounded rationality, framing, causation and effectuation in entrepreneurial decision making.
- Demonstrate an ability to design a business model canvas.
- Evaluate the various sources of raising finance for startup ventures.
- Understand the fundamentals of developing and presenting business pitching to potential investors.

REFERENCES

1. Ries, Eric (2011), The lean Start-up: How constant innovation creates radically successful businesses, Penguin Books Limited.
2. Blank, Steve (2013), The Startup Owner's Manual: The Step-by-Step Guide for Building a Great Company, K&S Ranch.
3. S. Carter and D. Jones-Evans, Enterprise and small business- Principal Practice and Policy, Pearson Education (2006)
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5. Osterwalder, Alex and Pigneur, Yves (2010) Business Model Generation.
6. Kachru, Upendra, India Land of a Billion Entrepreneurs, Pearson
7. Bagchi, Subroto, (2008), Go Kiss the World: Life Lessons for the Young Professional, Portfolio Penguin

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21UPEST2E18 BIO ENERGY TECHNOLOGIES

OBJECTIVES

- To detail on the types of biomass, its surplus availability and characteristics.
- To create awareness on the technologies available for conversion of biomass to energy in terms of its technical competence and economic implications.
- To impart knowledge on stoichiometry and combustion of bio fuels
- To elucidate on the influence of equivalence ratio on thermochemical conversion of biomass
- To provide insight to the possibilities of producing liquid fuels form biomass

UNIT I INTRODUCTION

Biomass: types – advantages and drawbacks – Indian scenario – characteristics – carbon neutrality – conversion mechanisms – fuel assessment studies – densification technologies – Comparison with coal – Proximate & Ultimate Analysis - Thermo Gravimetric Analysis

UNIT II BIOMETHANATION

Microbial systems – phases in biogas production – parameters affecting gas production – effect of additives on biogas yield – possible feed stocks. Biogas plants – types – design – constructional details and comparison – biogas appliances

UNIT III COMBUSTION

Perfect, complete and incomplete combustion - stoichiometric air requirement for biofuels - equivalence ratio – fixed Bed and fluid Bed combustion – fuel and ash handling system s – steam cost comparison with conventional fuels

UNIT IV GASIFICATION, PYROLYSIS AND CARBONISATION

Chemistry of gasification - types – comparison – application – performance evaluation – economics – dual fueling in IC engines – gas cooling and cleaning systems - Pyrolysis - Classification - process governing parameters – Typical yield rates. Carbonization Techniques – merits of carbonized fuels

UNIT V LIQUIFIED BIOFUELS

History of usage of Straight Vegetable Oil (SVO) as fuel - Biodiesel production from oil seeds, waste oils and algae - Process and chemistry - Biodiesel health effects / emissions / performance.

OUTCOMES

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

- Estimate the surplus biomass availability of any given area
- Design a biogas plant for a variety of biofuels
- Determine and compare the cost of steam generation from biofuels with that of coal and petroleum fuels
- Analyze the influence of process governing parameters in thermochemical conversion of biomass
- Synthesize liquid biofuels for power generation from biomass

REFERENCES

1. Tom B Reed, Biomass Gasification – Principles and Technology, Noyce Data Corporation, 1981
2. David Boyles, Bio Energy Technology Thermodynamics and costs, Ellis Hoknood Chichester, 1984.
3. Khandelwal KC, Mahdi SS, Biogas Technology – A Practical Handbook, Tata McGraw Hill, 1986
4. Mahaeswari, R.C. Bio Energy for Rural Energisation, Concepts Publication,1997

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21UPEST2E19 ENERGY EFFICIENT BUILDINGS DESIGN

OBJECTIVES

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

UNIT I INTRODUCTION

Conventional versus Energy Efficient buildings – Historical perspective - Water – Energy – IAQ requirement analysis – Future building design aspects – Criticality of resources and needs of modern living

UNIT II LANDSCAPE AND BUILDING ENVELOPES

Energy efficient Landscape design - Micro-climates – various methods – Shading, water bodies- Building envelope: Building materials, Envelope heat loss and heat gain and its evaluation, paints, Insulation, Design methods and tools.

UNIT III HEATING, VENTILATION AND AIR-CONDITIONING

Natural Ventilation, Passive cooling and heating - Application of wind, water and earth for cooling, evaporative cooling, radiant cooling – Hybrid Methods – Energy Conservation measures, Thermal Storage integration in buildings

UNIT IV HEAT TRANSMISSION IN BUILDINGS

Surface co-efficient: air cavity, internal and external surfaces, overall thermal transmittance, wall and windows; Heat transfer due to ventilation/infiltration, internal heat transfer; Solar temperature; Decrement factor; Phase lag. Design of daylighting; Estimation of building loads: Steady state method, network method, numerical method, correlations; Computer packages for carrying out thermal design of buildings and predicting performance.

UNIT V PASSIVE COOLING & RENEWABLE ENERGY IN BUILDINGS

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. Introduction of renewable sources in buildings, Solar water heating, small wind turbines, stand-alone PV systems, Hybrid system – Economics. Characteristics of DC and AC motor for various applications - starting and speed control - methods of braking.

OUTCOMES

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

- Will be familiar with climate responsive building design and basic concepts
- Will Know the basic terminologies related to buildings
- Will Know the passive (air) conditioning techniques

- Will be able to evaluate the performance of buildings
- Gets acquainted with Renewable energy systems in buildings

REFERENCES

1. Clarke, Joseph. Energy simulation in building design. Routledge, 2007
2. Krishan, Arvind, ed. Climate responsive architecture: a design handbook for energy efficient buildings. Tata McGraw-Hill Education, 2001
3. Krieder, J and Rabi, A., Heating and Cooling of buildings: Design for Efficiency, McGraw Hill, 1994.
4. UrsalaEicker, "Solar Technologies for buildings", Wiley publications, 2003.
5. Guide book for National Certification Examination for Energy Managers and Energy Auditors (Could be downloaded from www.energymanagertraining.com)

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21UPEST2E20 ENERGY FORECASTING, MODELING AND PROJECT

OBJECTIVES MANAGEMENT TECHNIQUE

- To understand about National energy scenario.
- To predict the energy demand using various forecasting models.
- To develop an optimization model for the effective utilization of energy sources.
- To know the procedure to the write the project proposal.
- To know the energy policies in the country.

UNIT I ENERGY SCENARIO

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

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

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

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

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)

OUTCOMES

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

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

REFERENCES

1. S. Makridakis, Forecasting Methods and applications. Wiley 1983
2. Austin H. Church, centrifugal pumps and blowers, John Wiley and sons, 1980.
3. Yang X.S. Introduction to mathematical optimization: From linear programming to Metaheuristics, Cambridge, Int. Science Publishing, 2008
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7. Sukhvinder Kaur Multani, Energy Security in Asia Current Scenario, The ICFAI University Press, 2008

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SUPPORTIVE COURSES

21UPEST2S01 BASIC CONCEPTS IN ENERGY SCIENCES

OBJECTIVES

- To get a knowledge about the energy sources
- To analyze the working principle, pros and cons of Conventional energy conversion techniques
- To know the impact of non-renewable energy systems on the environment.
- To know the importance and methods of conversion of bio-based waste into useful form of energy.
- Direct energy conversion systems Need and necessity of energy storage systems and their desirable characteristics & Fuel cells

UNIT –I ENERGY SOURCES

Environment and sustainable development - Energy sources - sun as the source of energy – photosynthesis - classification of energy sources - fossil fuel reserves and resources - overview of global/ India's energy scenario.

UNIT- II SOLAR ENERGY

Solar radiation: measurements and prediction - Solar thermal energy conversions systems: flat plate collectors - solar concentrators and other applications - Solar Photovoltaic: Principle of photovoltaic conversion of solar energy.

UNIT – III WIND ENERGY

Wind Resource: Meteorology of wind, India's wind energy potential and challenges - distribution across the world - Eolian features - Biological indicators - Wind measurement systems - Wind Energy Conversion Systems.

UNIT- IV BIOENERGY

Biomass as energy resources - Classification and estimation of biomass - Source and characteristics of biofuels – Biodiesel – Bioethanol – Biogas - Waste to energy conversions.

UNIT- V GEOTHERMAL ENERGY

Introduction - Geothermal sources - advantages and disadvantages of geothermal energy over other energy forms - Geothermal energy in India: Prospects - Applications of Geothermal energy - Material selection for geothermal power plants

OUTCOMES

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

- Awareness on the energy status in India as well as globe and familiarized in the different form of energy sources and energy conversion techniques.
- Able to select the suitable energy source based on the working principle, pros and cons of energy conversion systems.

- The knowledge about importance of energy conservation and the impact of non- renewable energy sources.
- To understand the concept of conversion of bio-based waste into useful form of energy.
- Awareness on the existence of various mechanisms for conversion and storage of energy, their merits, constraints and drawbacks

REFERENCES:

1. D. A. Spera, Wind Turbine Technology: Fundamental concepts of Wind Turbine Engineering, ASME Press.
2. S.P. Sukhatme, Solar Energy: principles of Thermal Collection and Storage, Tata McGraw-Hill (1984).
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21UPEST2S02 CLIMATE CHANGE AND CO_2 EMISSION ASSESSMENT

OBJECTIVES

- To study the global climate change
- To analysis emission assessment
- To familiarize about impact of climate changes on the environment.
- To know the carbon dioxide conversion and carbon footprint
- To understand the concept of carbon credit.

UNIT-I INTRODUCTION TO ENERGY

Introduction to Energy: Overview of energy sources and technologies - energy consumption Pattern - social and economic implications of energy uses - equity and disparity.

UNIT-II INTRODUCTION TO GLOBAL CLIMATE CHANGE

Introduction to global climate change: theory of global climate change - mechanism of Greenhouse Gases Emission - theory and proof of climate change impacts - global overview - International concern on Climate change and mitigation efforts.

UNIT-III CARBON DIOXIDE (CO2) EMISSIONS AND CONVERSION/CONSUMPTION

Carbon dioxide (CO2) emissions in relation to energy conversion/consumption: theory of CO2 emission in relation to energy conversion processes.

UNIT- IV METHODOLOGY FOR CO2 ASSESSMENT/CARBON FOOT PRINT

Methodology for CO2 assessment/carbon foot print: estimation of emission from fossil fuel combustion (Fuels and their composition - fuel to energy conversion - concept of emission factor) - emission from major sectors (industry – transport – agriculture – domestic - service)

UNIT-V CARBON CREDIT

Carbon credit: Definition - concept and examples - Carbon credit - national policies vis-à-vis international market scenario - Current efforts and future prospect/limitation of carbon trading mechanism.

OUTCOMES

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

- Depth knowledge in global climate change and the impact of climate change on the living things.
- Able to analysis emission characteristics and its impact on the globe.
- Obtained elaborate knowledge about impact of climate changes on the environment.
- Knowledge on carbon dioxide conversion and carbon footprint
- Knowledge on concept of carbon credit and their importance.

REFERENCES:

1. Franchetti M. J. and Apul D. S., Carbon Footprint Analysis: concepts, methods, implementation and case studies, CRC Press, (2013).
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3. Stern N.,The Economics of Climate Change. The Stern Review. Cambridge University Press, (2007).
4. Barrett S. Why Cooperate? The Incentive to Supply Global Public Goods. Oxford University Press, (2007).

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21UPEST2S03 ENERGY AND ENVIRONMENTAL IMPACTS

OBJECTIVES

- To teach the principal of energy and environmental issues
- To explore the environmental impact of various energy sources and also the effects of different types of pollutants.
- To know the solar energy and conversion technologies.
- To understand the biomass and geothermal energy systems and conversion techniques.
- To get an elaborate knowledge on pollution control methods.

UNIT-I ENERGY SOURCES

Present Energy resources in India and its sustainability - Different type of conventional Power Plant--Energy Demand Scenario in India-Advantage and Disadvantage of conventional Power Plants – Conventional vs Non-conventional power generation

UNIT-II SOLAR ENERGY

Basics of Solar Energy- Solar Thermal Energy- Solar Photovoltaic- Advantages and Disadvantages-Environmental impacts and safety.

UNIT-III BIOMASS AND GEO THERMAL ENERGY

Biomass resources-Biomass conversion Technologies- Feedstock preprocessing and treatment methods- Bioenergy program in India-Environmental benefits and impacts - Geothermal Energy resources –Ocean Thermal Energy Conversion – Tidal.

UNIT-IV POLLUTION CONTROL

Air pollution- Sources, effects, control, air quality standards, air pollution act, air pollution measurement. Water pollution-Sources and impacts, Soil Pollution-Sources and impacts, disposal of solid waste.

UNIT-V ENVIRONMENTAL AFFECT FACTORS

Greenhouse gases – effect, acid rain. Noise pollution - Pollution aspects of various power plants. Fossil fuels and impacts, Industrial and transport emissions- impacts.

OUTCOMES

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

- Learned challenges and opportunities related to energy use and conversion. Learn how to evaluate the sustainability of energy systems.
- Able to analyze environmental impact of various energy sources and also the effects of different types of pollutants.
- Familiar knowledge on solar energy and conversion technologies.
- Good knowledge on biomass and geothermal energy systems and conversion techniques.
- Elaborate knowledge on pollution control methods.

REFERENCES:

1. B H Khan, 'Non-Conventional Energy Resources'-The McGraw –Hill Second edition.
2. Boyle, G. Renewable energy: Power for a sustainable future'. Oxford University press, (2004).

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21UPEST2S04 ERECTION AND MAINTENANCE OF REFRIGERATION AND AIR-CONDITIONING EQUIPMENT'S

OBJECTIVES

- To analyze the working principle, pros and cons of Conventional energy conversion techniques.
- To know about energy-based testing measurement
- To know about energy-based measurement & maintenance system
- To get good knowledge in R & AC systems.
- To get a knowledge in maintenance.

UNIT-I INTRODUCTION

Refrigeration and air-conditioning plant layout, parameters affecting the location.

UNIT-II ERECTION OF R&AC SYSTEMS

Erection methodology, foundation, padding, network analysis, critical path, interconnections; safety precautions, air handling equipment's. Maintenance procedures.

UNIT-III TESTING OF EQUIPMENTS

Testing of compressors, condensers, evaporators, cooling towers, motors, controls, test rings, ISI standards. Testing of control systems, circuitry and troubleshooting, condition monitoring

UNIT-IV TOTAL PREVENTIVE MAINTENANCE

TPM Principles, Corrective and preventive measures and Reliability analysis.

UNIT-V MAINTENANCE SCHEDULES

Studies on different maintenance schedules followed by various industries

OUTCOMES

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

- Awareness on the existence of various instrument objective and their merits, constraints and drawbacks
- Knowledge on various kinds of R & AC systems.
- Able to measure and design an appropriate AC system.
- Good knowledge on maintenance.

REFERENCES

1. Arora C.P., Refrigeration and Air conditioning II Ed. McGraw-Hill, Pub., (2000).
2. ASHRAE Hand book on Refrigeration & Air conditioning, Published by ISHRAE, Bangalore, (1998).

CO	PO												PSO		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**1**	**2**	**3**
1	-	-	L	l	M	M	H	M	-	-	M	H	M	L	L
2	-	-	L	L	M	M	H	M	-	-	M	H	M	L	L
3	-	-	L	L	M	M	H	M	-	-	M	M	M	L	L
4	-	-	L	L	M	M	H	M	-	-	M	M	M	L	L
5	-	-	L	L	M	M	M	M	-	-	M	H	M	M	L

21UPEST2S05 GREEN CONCEPTS IN BUILDINGS

OBJECTIVES

- To understand and apply the concept of availability and to calculate the behavior of real gases
- To predict the condition of systems and analyze them by the criteria of equilibrium
- To know the building technologies
- To get a knowledge on use of solar energy in green buildings.
- To know the concept of green composites for buildings.

UNIT –I ENVIRONMENTAL IMPLICATIONS OF BUILDINGS

Environmental implications of buildings energy, carbon emissions, water use, waste disposal; Building materials: sources, methods of production and environmental Implications. Embodied Energy in Building Materials: transportation Energy for Building Materials; Maintenance Energy for Buildings.

UNIT- II IMPLICATIONS OF BUILDING TECHNOLOGIES

Implications of Building Technologies Embodied Energy of Buildings: Framed Construction, Masonry Construction. Resources for Building Materials, Alternative concepts. Recycling of Industrial and Buildings Wastes. Biomass Resources for buildings.

UNIT –III COMFORTS IN BUILDING

Comforts in Building: Thermal Comfort in Buildings- Issues; Heat Transfer Characteristic of Building Materials and Building Techniques. Incidence of Solar Heat on Buildings- Implications of Geographical Locations.

UNIT- IV UTILITY OF SOLAR ENERGY IN BUILDINGS

Utility of Solar energy in buildings concepts of Solar Passive Cooling and Heating of Buildings. Low Energy Cooling. Case studies of Solar Passive Cooled and Heated Buildings.

UNIT- V GREEN COMPOSITES FOR BUILDINGS

Green Composites for buildings: Concepts of Green Composites. Water Utilization in Buildings, Low Energy Approaches to Water Management. Management of Solid Wastes. Management of Sullage Water and Sewage. Urban Environment and Green Buildings. Green Cover and Built Environment.

OUTCOMES

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

- To calculate the availability of the systems and cycles
- Analyze the engineering systems to improve and optimize its performance
- Elaborate knowledge on the building technologies
- Able to apply solar energy in green buildings.
- Familiar in the concept of green composites for buildings.

REFERENCES:

1. Low Energy Cooling for Sustainable Buildings. John Wiley and Sons Ltd, (2009).
2. K.S.Jagadish, B. U. Venkataramareddy and K. S. Nanjundarao. Alternative Building Materials and Technologies. New Age International, (2007).

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
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2	M	M	L	-	-	L	H	L	-	-	M	H	M	-	M
3	M	M	L	-	-	H	H	L	-	-	M	M	M	-	M
4	M	M	L	-	-	L	H	L	-	-	M	H	M	-	M
5	M	M	L	-	-	L	H	L	-	-	M	H	M	-	M

VALUE ADDED COURSE

21UPESTVA01 ALTERNATE FUELS AND EMISSIONS

OBJECTIVES

- To present a problem oriented in depth knowledge of Alternate fuel and energy system
- To address the underlying concepts and methods behind alternate fuel and energy system
- To know the basics of engine emission standards

UNIT I INTRODUCTION

IC engines classifications (SI & CI engine, 2-stroke & 4-stroke engine), Thermodynamic Cycles Combustion in IC engine: Thermochemistry of Fuel-Air mixture, characterization of flame, Combustion stoichiometry, Chemical equilibrium, Chemical kinetics Properties of fuel and its effect on combustion: Engine knock & detonation, abnormal combustion

UNIT II ALTERNATE FUELS, PROPERTIES, SUITABILITY AND EMISSIONS

CNG, LPG, H2, Hythane, Di-Methyl Ether, Ethanol, Biodiesel

UNIT III NOVEL TECHNOLOGIES AND STRATEGIES TO CURB EMISSIONS

Homogeneous charge CI (HCCI) engines, Premixed Charge Compression Ignition (PCCI), Emission control technologies (EGR, SCR, DOC, DPF etc.) (To be updated periodically with new technologies and strategies)

OUTCOMES

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

- The student can identify different areas of alternate fuels and energy system.
- Can find the applications of all the areas in day-to-day life.
- Will understand the emission norms

REFERENCES

1. Internal Combustion engine fundamentals: J B Heywood, Tata Mc-Graw Hill Publications
2. Internal Combustion Engines: V Ganeshan, Tata Mc-Graw Hill Publications
3. IC Engines: Combustion and Emissions: BP Pundir, Narosa Publishing House
4. The Internal combustion Engine in theory and practice: C F Taylor, MIT Press, Cambridge
5. Alternative Fuels Guidebook, Properties, Storage, Dispensing, and Vehicle Facility Modifications: RL. Bechtold, SAE Publications, 1997

21UPESTVA02 BIOMASS AND ITS CONVERSION TECHNOLOGIES

OBJECTIVES

- Identify potential biomass feedstocks including energy crops;
- Have an understanding of the existing and emerging biomass to energy technologies;
- Develop a critical thinking about sustainability & resilience; and
- Determine potential solutions for energy needs and problems by incorporating the bioenergy technologies being explored.

UNIT I INTRODUCTION

Origin of Biomass: Resources: Classification and characteristics; Techniques for biomass assessment; Application of remote sensing in forest assessment; Biomass estimation.

UNIT II THERMO-CHEMICAL CONVERSION

Direct combustion, incineration, pyrolysis, gasification and liquefaction; Economics of Thermo-chemical conversion. biomass processing, briquetting, palletization, biomass stoves, biomass carbonization, production of syngas from biomass.

UNIT III BIOMASS PRODUCTIVITY

Energy plantation and power Programme. Biomass renewable energy program of central govt. and state government Regulations, policies, feed in tariff policies, grid injection, hybrid systems, and cost economics.

OUTCOMES

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

- Acquiring the knowledge of biomass energy.
- Understanding Biomass as an renewable energy and its importance with respect to environment protection
- To design bio-energy systems.

REFERENCES

1. Fuel Cells by Bockris and Srinivasan; McGraw Hill.
2. Solar Energy: Fundamentals and Applications by H.P. Garg& Jai Prakash, Tata McGraw Hill.
3. Wind Power Technology, Joshua Earnest, PHI Learning, 2014
4. Non-Conventional Energy Resources by S. Hasan Saeed and D. K. Sharma, S. K. Kataria & Sons.

21UPESTVA03 MATERIALS FOR ENERGY APPLICATIONS

OBJECTIVES

- To understand the concept of energy materials for energy generation.
- To analyze the material design, related to photovoltaic cell and energy storage
- To acquire information on phase change materials

UNIT I INTRODUCTION

Materials Glazing materials, Properties and Characteristics of Materials, Reflection from surfaces, Selective Surfaces: Ideal coating characteristics, Types and applications, Anti-reflective coating, Preparation and characterization. Reflecting Surfaces and transparent materials, Types of Insulation and properties.

UNIT II MATERIALS FOR PHOTOVOLTAIC'S CONVERSION

Si and Non-Si materials, crystalline, semi-crystalline, Polycrystalline and Amorphous materials, p-n junction: homo and hetero junctions, Metal-semiconductor interface

UNIT III PHASE CHANGE MATERIALS

Phase Change Materials Selection criteria of Phase change, Materials use in Solar heating or cooling, Research Status

OUTCOMES

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

- Apply the concept of materials required for energy storage and energy generation.
- Detailed study on properties of various energy-oriented materials for energy applications

REFERENCES

1. Solar Thermal Energy Storage by HP Garg, D Reidel Publishing Co.
2. Mathematical Modeling of Melting and Freezing process by V Alexiades and AD Solomon, Hemisphere Publishing Corporation, Washington.
3. Chemical and Electrochemical Energy System by R Narayan, B Viswanathan, Universities Press
4. Energy Storage Systems by B Kilkis and S Kakac (Ed), KAP, London

21UPESTVA04 ELECTRIC VEHICLES

OBJECTIVES

- To present a comprehensive overview of Electric and Hybrid Electric Vehicle
- To know about the sources of energy for electrical vehicles
- To obtain knowledge on storage techniques on electrical vehicles.

UNIT I INTRODUCTION

The Electric Vehicle Debate, Primary Energy Sources and Alternative Fuels for Transportation, History of electric Vehicles, Electrochemical Power Sources –Secondary Batteries and Fuel Cells

UNIT II SOURCES

Aqueous Electrolyte Batteries –Lead Acid, Nickel – Iron, Nickel – Zinc, Metal – Air Zinc – Halogen - Non-Aqueous Electrolyte Batteries- High Temperature Batteries, Organo Electrolyte and Solid-State Batteries

UNIT III OVERVIEW OF HYBRID ELECTRIC VEHICLES

Combustion Engine Hybrid Electric Vehicles, Laboratory Test of Electric Vehicle Batteries, Vehicle tests with Electric Vehicle Batteries, Future of Electric Vehicles

OUTCOMES

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

- Choose a suitable drive scheme for developing an electric of hybrid vehicle depending on resources
- Design and develop basic schemes of electric vehicles and hybrid electric vehicles.
- Understanding electric car energy resources -
- Experience of electric car storage technology.

REFERENCES

1. Hand Book of Batteries and Fuel cells, 3rd Edition, Edited by David Linden and Thomas. B. Reddy, McGraw Hill Book Company, N.Y. 2002.
2. Fuel Cells, Principles and Applications, Viswanathan, B. and Scibioh, Aulice M, Universities Press, 2006.
3. The Essential Hybrid Car Handbook: A Buyer's Guide (Paperback)by Nick Yost, The Lyons Press, N.Y. 2006.

21UPESTVA05 DESIGN THINKING

OBJECTIVES

- To introduce the idea of design thinking in product development
- To understand the practice of design thinking
- To leverage use of tools for the design process
- To learn the application of design thinking for the IT industry
- To design using the methodology

UNIT I INTRODUCTION

Understanding Design thinking – Shared model in team-based design – Theory and practice in Design thinking – Exploring work of Designers across globe – MVP or Prototyping

UNIT II TOOLS FOR DESIGN THINKING

Real-Time design interaction captures and analysis – Enabling efficient collaboration in digital space – Empathy for design – Collaboration in distributed Design

UNIT III DESIGN THINKING IN IT

Design Thinking to Business Process modeling – Agile in Virtual collaboration environment – Scenario based Prototyping

OUTCOMES

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

- Apply design thinking for product development
- Use design thinking tools
- Identify need for products and disruption
- Design innovative products

REFERENCES

1. Roger Martin, "The Design of Business: Why Design Thinking is the Next Competitive Advantage", Harvard Business Press, 2009.
2. Hasso Plattner, Christoph Meinel and Larry Leifer (eds), "Design Thinking: Understand – Improve – Apply", Springer, 2011 (Unit III).
3. Idris Mootee, "Design Thinking for Strategic Innovation: What They Can't Teach You at Business or Design School", John Wiley & Sons 2013. (Unit IV).