MA501					Mathematical Techniques					
Teaching Scheme					**Examination Scheme**					
L	**T**	**P**	**C**	**Hrs/Week**	**Theory**			**Practical**		**Total Marks**
					MS	**ES**	**IA**	**LW**	**LE/Viva**	
					25	**50**	**25**	**--**	**--**	**100**

COURSE OBJECTIVES

- To understand the concepts of Fourier analysis and its applications.
- To understand Laplace transforms and its applications to differential equations.
- To understand the concepts of vector calculus, matrices and applications.
- To understand the methods complex analysis for integration and conformal mapping.
- To introduce the concept of probabilistic random variables and their applications.
- To introduce the concept of statistical sampling, estimation methods, and hypothesis testing.

UNIT 1 Fourier analysis and transforms **10 Hrs.**

Fourier Seies, Dirichlet conditions, Fourier coefficients, discontinuous functions, non-periodic functions, Complex fourier series, Parseval's theorem, Fourier Integral and Transforms, Properties, convolution and deconvolution, relation of Dirac Delta function to Fourier Transform, Parseval's theorem, Fourier transform in higher dimensions. Applications.

UNIT 2Laplace Trasforms, higher order differential equations and PDEs **12 Hrs.**

Laplace Transforms of a functions, derivatives and integrals, other properties, applications to solving differential equations, Higher order differential equations, Series solutions of ordinary differential equations, Eigenfunction methods, partial differential equations, general and particular solutions.

UNIT 3Vector calculus and complex analysis and matrices. **12 Hrs.**

Vector calculus in single and multiple variables, gradients, divergence, curl, line integral, Green's theorem, surface integral, Stoke's Theorem,Applications.Complex Analytic Functions, Complex Integrals, Laurent Series,Complex Integration by Method of Residues, Conformal Mapping and Applications.Matrices : basic concepts, Inverse of matrix, solutions of linear systems, Eigen values, eigenvectors, symmetric matrices, complex matrices.

UNIT 4Probability theory and Statistics. **12 Hrs.**

Probability axioms and theorems, permutations and combinations, random variables and distributions, properties of distributions, Functions of random variables, generating functions, central limit theorem, Joint distributions. Statistical experiments, samples and populations, sample statistics, estimators and sampling distributions, maximum likelihood estimate, least squares, Hypothesis testing.

Max. <40> Hrs.

COURSE OUTCOMES

On completion of the course, student will have the

CO1 –understanding ofthe concepts of Fourier analysis and its applications.

CO2 –Understanding of Laplace transforms and its applications to differential equations

CO3 –Understanding the concepts of vector calculus, matrices and applications

CO4 –knowledge of the methods complex analysis for integration and conformal mapping.

CO5 –knowledge ofthe concept of probabilistic random variables and their applications.

CO6 –knowledge the concept of statistical sampling, estimation methods, and hypothesis testing.

TEXT/REFERENCE BOOKS

1. KF Riley, MP Hobson, SJ Bence,Mathematical Methods for Physics and Engineering 3rd ed., Cambridge 2006.
2. Mary L. Boas, Mathematical Methods for the Physical Sciences, John Wiley and Sons Inc. 2006.
3. E. Kreyszig, Advanced Engineering Mathematics 9th ed, John wiley& sons.
4. Arfken and Weber, Mathematical Methods for Physicists 6th ed. Elsevier (2005).
5. KF Riley, MP Hobson, SJ Bence,Mathematical Methods for Physics and Engineering 3rd ed., Cambridge 2006.
6. Earl A. Coddington, An Introduction to Ordinary Differential Equations. Prentice-Hall India (1968).
7. Mark J. Ablowitz and Athanassios S. Fokas Complex Variables: Introduction and Applications (Cambridge Texts in Applied Mathematics), Cambridge, 2003)
8. Tristan Needham, Visual Complex Analysis. Oxford University Press (1999).

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**

Part A/Question: <Details> <> Marks

Part B/Question: <Details> <> Marks

SE 502					Quantum Mechanics and Semiconductors					
Teaching Scheme					**Examination Scheme**					
L	**T**	**P**	**C**	**Hrs/Week**	**Theory**			**Practical**		**Total Marks**
					MS	**ES**	**IA**	**LW**	**LE/Viva**	
3	**0**	**0**	**3**	**3**	**25**	**50**	**25**	**--**	**--**	**100**

COURSE OBJECTIVES

- Know the background and the main features in the historical development of quantum mechanics
- Understand the phenomena which are unable to be explained by classical mechanics
- Understand the principle of matter-waves and their mathematical formulation
- To understand phenomena which occur at atomic level with their gross effect that we realize
- Using the framework of quantum mechanics to introduce semiconductor fundamentals
- Using the framework of quantum mechanics to understand the principle of nanotechnology
- Using the framework of quantum mechanics to understand the principle of electron microscopies

UNIT 1 Foundation of Quantum Mechanics 8 Hrs.

Origin of quantum theory: Failure of classical theory, Matter-waves & Uncertainty principle.

UNIT 2 Quantum Mechanical Problems and their Solutions 14 Hrs.

2.1. Wave Packets and Free-Particle Motion: Schrodinger equation, expectation values, 1D Gaussian wave packet, One dimensional solution of Schrodinger equation.

2.2. Quantum well problem: Particle in 1D infinitely deep potential well, finite depth potential well.

2.3. Barrier transmission problem: 1D potential step, rectangular barrier problem, periodic potential barrier

UNIT 3 Theory of Semiconductors in Quantum Mechanical Understanding 6 Hrs.

Energy band in semiconductors, Band theory, *E-K* relations, Direct& Indirect band gap, temperature dependence of band gap

UNIT 4 Optical and Electrical Processes in Semiconductors 12 Hrs.

4.1 Intrinsic Carriers, their concentration, Density of States for electron & holes, Fermi levels, equilibrium & non-equilibrium states in semiconductors.

4.2 Generation & Recombination of carriers, minority carriers & lifetimes

4.3 Carrier motion in semiconductors; Drift, mobility & conductivity

4.4 Drift and Diffusion of carriers in semiconductor

Max. <40> Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 – Identify physical processes of nature which cannot be described by classical physics

CO2 – Understand concept of matter waves and uncertainty principles.

CO3 – Apply theories of quantum mechanics to solve problems of energy quantization.

CO4 – Relate quantum mechanical theories to explain energy processes in materials.

CO5 – Interpret optical and electronic processes in solid semiconductor crystals.

CO6 – Design new energy devices using quantum physical approach.

TEXT/REFERENCE BOOKS

1. Ajoy Ghatak & S. Lokanathan, Quantum Mechanics: Theory and Applications, 5 Ed., Macmilan India, 2004.
2. J. Milman & C.C. Halkias, Integrated Electronics, Tata McGraw Hill
3. Charles Kittel, Introduction to Solid State Physics, 8th Edition, Wiley,2004.
4. S.M. Sze & Kwok K. Ng, Physics of Semiconductor Devices, Weiley Student Ed., 3Ed.

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100	**Exam Duration: 3 Hrs**
Part A/Question: Descriptive	5x12 = 60 Marks
Part B/Question: Problem solving	5x6 = 30 Marks
Part C/ Question: Concept base	5x2 = 20 Marks

<SE 503>					<Thermodynamics and Heat Transfer>					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

1. To introduce and define the laws of Thermodynamics and modes of Heat Transfer.
2. To familiarize the conservation principles and performance analysis of various cycles.
3. To enable the students to understand and apply the laws of heat transfer for thermal systems.
4. To demonstrate the working and calculations using EES tool for various industrial applications.

UNIT 1 <TITLE> 8 Hrs.

< **Fundamental concept:** Thermodynamic system and control volume, Thermodynamic properties, Processes and cycles, Thermodynamic equilibrium, Quasi-static process

First Law of Thermodynamics: Various types of energies, First law for a closed system and open system; Properties of pure substance; Application of EES software for numerical solutions.

Second Law of Thermodynamics: Kelvin-Plank and Clausius' statements, equivalence of the statements, Causes of irreversibility, Carnot theorem and its corollary, Thermodynamic temperature scale>

UNIT 2<TITLE> 10 Hrs.

< **Entropy**: Clausius theorem, The property of entropy, inequality of Clausius, Principle of increase of entropy and its application

Available Energy, Exergy and Irreversibility – High and low grade energy, Available and unavailable energy, availability (exergy) of closed; steady flow; and open system processes, irreversibility

Thermodynamic Cycles: Rankine cycle, Joule cycle, Sterling cycle, Otto, Diesel and Dual cycles>

UNIT 3<TITLE> 10 Hrs.

< **Conduction –** Derivation of generalized equation in Cartesian and cylindrical coordinates, one-dimensional steady state heat transfer equations for slabs, cylinders, spheres use of electrical analogy, one dimensional transient heat conduction in solids, Necessity of extended surfaces, heat

transferred under different boundary conditions, fin effectiveness and fin efficiency, Critical thickness of insulation>

UNIT 4<TITLE> **12 Hrs.**

< **Convection –** Lumped system analysis, Dimensionless number and their use, derivation of generalized equation in dimensionless groups for free & forced convection by dimensional analysis and principle of similarity, use of empirical co-relations to determine heat transfer co-efficient in natural and forced convection; Natural convention inside enclosures.

Radiation – Concept of black and grey surfaces, various laws of radiation, heat exchange between black and grey surfaces and enclosed body and enclosure, radiation shield and their effects, use of electrical analogy methods>

Max. <40> Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 - < Define the “fundamentals terminologies” used in Thermodynamic laws and modes of heat transfer.>

CO2 - < Analyze the thermodynamic systems using conservation principles>

CO3 - < Examine the performance of thermodynamic cycles >

CO4 - < Evaluate the conduction heat transfer rate for different applications>

CO5 - < Identify and apply the convection correlations to determine convection heat transfer rate >

CO6 - < Compile the information regarding fundamentals and applications of Radiation heat trasfer.>

TEXT/REFERENCE BOOKS

1. <Thermodynamics: An Engineering Approach by Yunus A Cengel and Michael A boles, Mc Graw Hill>
2. < Engineering Thermodynamics by P K Nag>
3. < Heat and Mass Transfer: Fundamentals and Applications by Yunus A Cengel and Michael A boles, Mc Graw Hill>
4. Heat Transfer by J P Holman>

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3Hrs**

Unit 1/Question: <Question 1 with subsections(with internal choice)>	<20> Marks
Unit 2/Question: < Question 2 with subsections(with internal choice)>	<20> Marks
Unit 3/Question: <Question 3 with subsections(with internal choice)>	<30> Marks
Unit 4/Question: < Question 4 with subsections(with internal choice)>	<30> Marks

SE504					Vacuum Science & Thin Film Technology					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	40	25	50	25	--	--	100

COURSE OBJECTIVES

- 1. Impart concept of Pressure and Vacuum
- 2. To introduce knowledge on creating ultrahigh vacuum.
- 3. Make the student understand molecular theories of thin film
- 4. To know the ways of custom designing thin films
- 5. Application of thin films in solar cell, batteries and supercapacitors

UNIT 1 Kinetic theory, Vacuum and Its Measurement 10 Hrs.

Behavior of Gases: Gas Transport Phenomenon, Viscous, Molecular and Transition flow regimes; Measurement of Pressure, Residual Gas Analyses; Production of Vacuum – Mechanical Pumps (rotary, turbo molecular pumps), Diffusion pump, Getter and Ion pumps, Cryo-pumps, Vacuum Gauges, Materials in Vacuum; High Vacuum, and Ultra High Vacuum Systems; Leak Detection.

UNIT 2 Physical Vapor Deposition 12 Hrs.

Hertz Knudsen equation; Mass evaporation rate; Knudsen cell, Directional distribution of evaporating species, Evaporation of elements, Compounds, Alloys, Raoult's law; e-beam, Pulsed laser and Ion Beam Evaporation, Reactive evaporation, Glow Discharge and Plasma, Sputtering– mechanisms and yield, dc and rf sputtering, Bias sputtering, Magnetically enhanced sputtering systems, reactive sputtering.

UNIT 3 Chemical Vapour Deposition 14 Hrs.

Reaction chemistry and thermodynamics of CVD; Thermal CVD, plasma enhanced CVD for amorphous silicon thin films, VLS and SLS mechanisms.

Spray Pyrolysis, Electrodeposition, Sol-Gel technique, Nucleation & Growth: capillarity theory, atomistic and kinetic models of nucleation, basic modes of thin film growth, stages of film growth & mechanisms.

UNIT 4 Epitaxy and Applications 4 Hrs.

Homo, Hetero and Coherent epilayers, Lattice misfit and imperfections, Epitaxy of compound semiconductors, Scope and Applications of thin films in solar cells, Batteries and Supercapacitors

Max. <40> Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 – Name various systems for creating ultra-high vacuum.

CO2 – Relate kinetic theory of gases to vacuum technology.

CO3 – Utilize physical and chemical vapour deposition to prepare thin films.

CO4 – Distinguish VLS and SLS mechanisms for the formation of thin films.

CO5 – Interpret the importance of thin film epitaxy in high end application.

CO6 – Develop strategies for the preparation of thin films for solar cell and batteries.

TEXT/REFERENCE BOOKS

1. Milton Ohring, Materials Science of Thin Films, Second Edition.
2. James M. Lafferty, Foundations of Vacuum Science and Technology
3. J.F. O'Hanlon, A User's Guide to Vacuum Science and Technology
4. Rao, Ghosh and Chopra, Vacuum Science and Technology

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**

Part A/Question: Analytical, Application oriented (from last 3 units 10 questions each of 10 marks	100 Marks
Part B/Question: Nil	-

<table>
<tr><th colspan="5">SE 505</th><th colspan="6">Renewable Energy Management and Energy Efficiency</th></tr>
<tr><th colspan="5">Teaching Scheme</th><th colspan="6">Examination Scheme</th></tr>
<tr><th rowspan="2">L</th><th rowspan="2">T</th><th rowspan="2">P</th><th rowspan="2">C</th><th rowspan="2">Hrs/Week</th><th colspan="3">Theory</th><th colspan="2">Practical</th><th rowspan="2">Total Marks</th></tr>
<tr><th>MS</th><th>ES</th><th>IA</th><th>LW</th><th>LE/Viva</th></tr>
<tr><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td><td>25</td><td>50</td><td>25</td><td>--</td><td>--</td><td>100</td></tr>
</table>

COURSE OBJECTIVES

- Provides an introduction to renewable energy resources with an emphasis on alternate energy sources, their technology and applications.
- Explore the present needs of society and future energy demands.
- Examine and compare conventional energy sources and systems and then focus on alternate, renewable energy sources such as solar, biomass (conversions), wind power, geothermal, and hydropower.
- Understand energy efficiency models of savings of energy through lighting, heating and comfort usages.
- Learn energy audit.

UNIT 1 Renewable Energy Sources 14 Hrs.

Solar energy: Devices for thermal collection, solar energy applications; **Wind energy:** analysis of wind speeds, different types of wind turbines, Wind date, factors for site selection, performance characteristics; **Bio Energy:** Biomass gasifiers, types, design and construction of biogas plants, scope and future; Tidal, wave and ocean thermal energy conversion plants, geothermal plants

UNIT 2 Energy Management 6 Hrs.

Its importance, Steam Systems: Boiler efficiency testing, excess air control, Steam distribution, condensate recovery, flash steam utilization, Thermal Insulation Energy conservation in Pumps, Fans, Compressed Air Systems, Refrigeration & Air conditioning systems

UNIT 3 Thermal Energy Systems 14 Hrs.

Waste heat recovery: Recuperators, heat pipes, heat pumps, Cogeneration - concept, options (steam/gas turbines/diesel engine based), selection criteria, control strategy; **Heat exchanger networking:** concept of pinch, target setting, problem table approach, composite curves. Demand side management, financing energy conservation

UNIT 4 Energy Efficiency **6 Hrs.**

Energy Efficiency aspects, Efficient Lighting, Efficient Building (Heating & Cooling), Efficient Pumping, Energy Audit

Max. <40> Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 – Identify various RE systems

CO2 – Understand challenges and problems associated with the use of various RE sources

CO3 – Solve practical design problems in RE systems.

CO4 - Analyze the merits and demerits of systems incorporating energy efficient components

CO5 – Evaluate sustainability aspects of a given RE system.

CO6 – Design remedies/best possible solutions to the supply and environmental issues associated with primary energy resources

TEXT/REFERENCE BOOKS

1. Solar Energy by S P Sukhatme and J K Nayak
2. Solar Engineering of Thermal Processes by Duffie and Backman
3. Energy Management and Conservation Frank Kreith and D Yogi Goswami Handbook CRC press
4. TERI hand book on Energy Conservation
5. Industrial Energy Conservation Manuals, MIT Press
6. Heat Exchanger Network Synthesis- Process Optimisation by Energy and Resource Analysis by Uday V Shenoy, Gulf Publ. Company
7. Energy Efficiency: Principles and Practices (Hardcover) by Penni McLean-Conner
8. Energy Efficiency Manual: by Donald R. Wulfinghoff

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**

Part A/Question: Descriptive 50 Marks

Part B/Question: Numerical 30 Marks

Part C/Question: Design 20 Marks

SE 506					Energy Lab-1					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
0	0	4	2	4	00	00	00	50	50	100

COURSE OBJECTIVES

- Provides students a hands-on experience of the energy systems based on renewable resources.
- Provides primary experiences of application of solar cells under standard and various non-standard conditions (such as, varied illumination, temperatures etc)
- Make a survey of various renewable energy resources installed in different locations in and around the campus
- Demonstrate various thin film systems used for energy devices including solar cells.

The laboratory has three major components:

Resource survey: To study various renewable energy source options (PV, Wind etc.) installed in and around PDPU campus and write report.

Kit based experiments on solar cell characteristics:

Exp 1 – Identifying and measuring the parameters of a solar PV Module in the field
Exp 5 – Dark and Illuminated Current-Voltage characteristics of solar cell
Exp 6 – Solar cells connected in series and in parallel
Exp 7 – Dependence of Solar cell I-V characteristics on light intensity and temperature

Techniques and characterization of thin films for solar cell fabrication:

(i) To study non-vacuum thin film depositions such as Spray Pyrolysis and Spin Casting in developing thin films related to energy applications.

(ii) To characterize thin film by XRD and UV-Vis spectroscopy

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 – Identify renewable energy (RE) resources and their characteristics

CO2 – Understand working principles of various RE sources

CO3 – Practice data recording and their reporting

CO4 – Analyze experimental data on solar cells and characterize it

CO5 – Write report of experimental observation and their analysis

CO6 – Design new experiments and projects on solar photovoltaics

TEXT/REFERENCE BOOKS

1. Energy Lab Manual, Department of Solar Energy, PDPU
2. Equipment Manual, Spray Pyrolysis
3. Equipment Manual, Sputter Deposition Unit
4. Equipment Manual, Spin Coater
5. Equipment Manual, UV-Vis Spectrophotometer.

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**

Part A/Question: <Details> **<> Marks**

Part B/Question: <Details> **<> Marks**

SE 507					Semiconductor and Optoelectronic Devices (Elective)					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

- Understand the principle of semiconductor physics applicable in the formation of the device.
- Understand the mechanisms behind various components of the device, such as junction and contacts and their controlling parameters.
- Learn about mechanisms of light absorption and emission by semiconductors.
- Understand working principle of electroluminescent light emitting devices.

UNIT 1 Fundamental Semiconductor Physics 8 Hrs.

Solids & its microstructures; Energy Bands in Solids; Fermi Energies; Semiconductors: types, carrier concentration, Fermi Levels; Electrons & Holes in Semiconductors; Doping; Quasi Fermi Levels; Generation and Recombination in Semiconductors; Transport in Semiconductors: Electron and Hole transports, Diffusion of carriers, Continuity equation, Hall effect

UNIT 2 Semiconductor junctions: Properties and controlling parameters 12 Hrs.

P-N junctions at equilibrium & non-equilibrium; Metal-Semiconductor junctions and Schottky barrier devices; Metal-insulator-semiconductor junctions; Semiconductor heterojunctions.

UNIT 3 Optical processes in semiconductors 8 Hrs.

Emission and absorption of photons by semiconductors; Band-to-band transitions; Indirect intrinsic transitions; Exciton absorption; donor-acceptor and impurity-band absorption; Low energy absorption; Absorption in quantum-wells; Overview of Franz-Keldysh effect and Stark effects; Refractive Index, Kramers-Kronig Relations, complex nature of refractive index and introduction to extinction coefficient.

UNIT 4 Optoelectronic Devices 12 Hrs.

Radiation in semiconductors; Luminescence in Semiconductors. Luminescence from quantum-wells; Electroluminescent process & LEDs; Photodetectors; Junction photodiodes; Solar cells.

Max. <40> Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 – Identify various types of optoelectronic devices based on semiconductors.

CO2 – Understand functionalities of various semiconductor junctions and the dependency parameters.

CO3 – Apply the theories of semiconductor devices to solve design problems.

CO4 – Analyze device characteristics to explore critical parameters and new information.

CO5 - Develop thinking process to improve functionality of various semiconductor optoelectronic devices.

CO6 – Develop strategies for new design of solar cells, photodetectors, sensors, and light emitting devices.

TEXT/REFERENCE BOOKS

1. Physics of Semiconductor Devices, by S.M. Sze & Kwok K. Ng, Wiley Student Ed, 3rd Ed.
2. Integrated Electronics, by J. Milman & C.C. Halkias, Tata McGraw Hill
3. Introduction to Solid State Physics, C. Kittel, Wiley Student Ed, 7th Ed.
4. Physics of Solar Cells, by Peter Wurfel, Wiley VcH

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100	**Exam Duration: 3 Hrs**
Part A/Question: Subjective/ Descriptive	4 X 12 = 48 Marks
Part B/Question: Numerical problems	4 X 5 = 20 Marks
Part C/Question: Concept base	4 X 5 = 20 Marks
Part D/ Question: Device design	1 X 12 = 12 Marks

SE509					Solar Thermal Engineering					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

1. To introduce and define the basics concept of solar radiation modelling.
2. To familiarize the working principles of non-concentrated and concentrated collectors.
3. To enable the students to understand the details about the TES systems.
4. To demonstrate the working and calculations involved in heating and cooling load calculations and solar system application.

UNIT 1	12_ Hrs.
Solar Radiation and Modelling: Extra terrestrial and terrestrial radiations, instruments to measure solar radiation, solar radiation geometry, empirical correlations for predicting available solar radiation, computation of solar radiation on horizontal and tilted surfaces. Use of EES tool. **Solar flat plate collectors**: Construction, performance analysis, estimation of losses, collector efficiency and collector heat removal factor, testing procedures **Solar Air Heaters**: Performance analysis of Conventional Air heaters, testing procedures	
UNIT 2	**12_ Hrs.**
Concentrating collectors: Flat plate collector with booster mirror, cylindrical parabolic collectors, Fresnel collectors, compound parabolic collector, paraboloid dish collector, central receiver collector **Thermal Energy Storages**: sensible, latent and thermo-chemical storage	
UNIT 3	**8_ Hrs.**
Solar process load: Hot water load, space heating load, building loss coefficient, cooling load **Solar water heating**: Freezing, boiling and scaling, natural and forced circulation systems, integral collector storage systems, water heating in space heating and cooling, testing and rating of solar water heater, economics of solar water heating **Building heating (Active)**: Different types of systems, Parametric study, solar energy heat pump systems, solar heating economics	
UNIT 4	**8_ Hrs.**
Building heating (Passive and Hybrid Methods): Concept of passive heating, comfort criteria and heating load, movable insulation, shading, direct heat gain systems, hybrid systems, economics of passive heating **Solar cooling**: Solar absorption cooling, combined heating and cooling, simulation study of solar air conditioning, solar desiccant cooling, **Solar Industrial process heat**: integration with industrial design, mechanical design consideration, different types of system, economics of industrial process heat>	
	Max. <40> Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to
CO1 - < Define the “fundamentals terminologies” used in solar radiation.>
CO2 - < Design and analyze the solar flat plat collectors and air heaters. >
CO3 - < Examine the performance of concentrator collectors and TES systems. >
CO4 - < Evaluate the solar process load and water heating.>
CO5 - < Identify the principles of building heating and solar cooling methods. >
CO6 - < Compile the information regarding solar industrial process heat.>

TEXT/REFERENCE BOOKS

1. < Solar Energy by S P Sukhatme and J K Nayak >
2. < Principles of Solar Energy by D Yogi Goswami.>
3. < Solar Engineering of Thermal Processes by Duffie and Backman>

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**

Unit 1/Question: <Question 1 with subsections(with internal choice)>	<20> Marks
Unit 2/Question: < Question 2 with subsections(with internal choice)>	<20> Marks
Unit 3/Question: <Question 3 with subsections(with internal choice)>	<30> Marks
Unit 4/Question: < Question 4 with subsections(with internal choice)>	<30> Marks

16SE510T					Semiconductor Processing & Characterization					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	6	3	25	50	25	--	--	100

COURSE OBJECTIVES

1. To provide basic knowledge of the semiconductor physics and technology.
2. To describe and provide a fundamental understanding of techniques for design and engineering of semiconductors.
3. To challenge students with open ended design questions integrating the course material with materials from previous classes.
4. To provide the opportunity to compile engineering practical tools and guidelines that can be used in professional settings.

UNIT 1 SEMICONDUCTOR MATERIAL PROCESSING **7 Hrs.**

Crystal growth, High-temperature processing & implantation: diffusion, ion implantation, oxidation, Rapid Thermal Processing (RTP) Lithography: Optical and non-optical

UNIT 2 SOLAR CELL TECHNOLOGY **8 Hrs.**

Vacuum science and plasma, Etching: Wet etching, Chemical Mechanical Polishing (CMP), plasma etching, ion milling, Silicon Solar cell fabrications, CMOS, GaAs, MEMS.

UNIT 3 ELECTRICAL CHARACTERIZATION **13 Hrs.**

Electrical characterization: resistivity, carrier doping and density, contact -resistance and Schottky barriers, mobility, carrier lifetime, oxide and interface trapped charges Solar cell topics: current-voltage, series and shunt resistance, internal and external quantum efficiency.

UNIT 4 CHEMICAL AND PHYSICAL CHARACTERIZATION **12 Hrs.**

Optical characterization: microscopy, ellipsometry, X-ray diffraction, photoluminescence, Raman spectroscopy, Fourier Transform Infrared Spectroscopy (FTIR), Chemical and Physical characterization: Scanning Electron Microscopy (SEM), Auger Electron Spectroscopy (AES), Transmission Electron Microscopy (TEM), Electron Beam Induced Current (EBIC), Secondary ion mass spectrometry (SIMS)

Max. <40> Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to
CO1 – Identify materials and their chemical properties necessary for effective semiconductor package design.
CO2 – Analyze the behaviour of P-N junction and correlate with solar and sensor working.
CO3- Determine how to measure charge density in the depletion region.
CO4 – Understand the free-carrier Hall Effect, deep levels, and the Shockley-Read-Hall model.
CO5 – Able to understand about recombination physics, minority-carrier lifetime measurement, and minority-carrier diffusion length measurements. Learn defect identification by photoluminescence spectroscopy.
CO6 - Develop research approaches to assessing materials principles and summarize them as useful tools.

TEXT/REFERENCE BOOKS

1. The science and engineering of microelectronic technology by Stephen A. Campbell.
2. Semiconductor Material and Device Characterization by Dieter K. Schroder

3. Research Papers

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**

Part A/Question: <Details> <> Marks

Part B/Question: <Details> <> Marks

SE 511					Photovoltaic Science and Engineering					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

- To gain fundamental and applied knowledge on solar photovoltaic science and engineering.
- To understand losses and learn design of an efficient solar cell.
- To know about technologies for solar cells and their engineering aspects.
- To learn about PV modules and their design aspects.
- To learn designing PV systems and their balance-of-systems.
- To exercise practical design of PV power plants and their prefeasibility studies.

UNIT 1 Foundation, Design and Efficiency of Photovoltaic Cells **14 Hrs.**

Background & Over view of Photovoltaics; Generation & Recombination; Cell design aspect; Theoretical Efficiency - Shockley-Quiesser efficiency limit

UNIT 2 Photovoltaic Technologies **8 Hrs.**

Crystalline silicon solar cell technology; Thin film solar cells: Materials & methods of deposition; Commercial technologies - aSi, CdTe, CIGS; Emerging PV technologies: Hybrid, Perovskite; Light management schemes: ARC, Texturing, Plasmonics

UNIT 3 PV Modules and Systems – Balance of Systems **14 Hrs.**

PV Module & their connection; PV Module design and manufacturing; PV Systems & basic building blocks; PV balance-of-systems: Batteries; DC-DC Converter; MPPT Controller; Charge controller; Application of Batteries with PV system; Inverters & topologies; Power quality engineering

UNIT 4 Design of PV systems **4 Hrs.**

Pre sizing of PV systems; Ground mounted and rooftop PV systems; Hybrid PVS; Grid tied PVS; Design of a 1MW power plant; Writing DPR - Exercises

Max. <40> Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 -Recognize potential of solar energy as an alternative source of energy

CO2 - Understand the fundamental principles of solar photovoltaic science and its engineering aspects.

CO3 - Apply basic understanding to design a solar cell, module and systems.

CO4 - Analyze loss mechanisms and optimize design of a solar photovoltaic absorber.

CO5 - Asses prefeasibility of developing a solar PV system under the prevailing conditions of a given location on the earth.

CO6 - Innovate new technologies and designs of solar cells, modules and systems.

TEXT/REFERENCE BOOKS

1. Solar Photovoltaic by Chetan Singh Solanki
2. Physics of Solar Cells by Peter Wurfel
3. Solar cells: operating principles, technology and system applications by Martin A. Green
4. Applied Photovoltaic by S.R. Wenham, M.A. Green and M.E. Watt

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100	**Exam Duration: 3 Hrs**
Part A: 4 Questions of 3 marks each (Objective). Choices out of 5.	12 Marks
Part B: 4 Questions of 10 marks each (Descriptive). Choices out of 5.	40 Marks
Part C: 4 Questions of 8 marks each (Numericals). Choices out of 4.	32 Marks
Part D : 1 Question on design. No choice.	16 Marks

SE 512					Modelling and Simulations					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

- To understand the importance of Modeling and Simulation in Science and Engineering.
- Understand the basics for simulation of charge carrier transport by deterministic approach.
- Understanding the basics for simulation of charge carrier transport by probabilistic approach.
- Understand the methods of chemical interaction and reactive potential methods to simulate bulk properties of materials.
- Understand the quantum mechanical approaches to modelling and simulation.
- Understand the advanced modelling and simulation methods in the atomistic regime.

UNIT 1 Charge carrier transport and device simulation using deterministic methods 12 Hrs.

Review of Band Model of Solids, Thermal-Equilibrium Statistics,Boltzman Transport Equation, Approximate Solutions, Drift Diffusion equation, ScharfetterGummel Discretization Scheme, Examples.

UNIT 2 Charge carrier transport and device simulation using probabilistic methods 8 Hrs.

Introduction to Monte Carlo technique, Monte Carlo methods for Particle Based Device Simulation, Free flight Generation, Scattering Mechanisms for charge carriers in materials, Final state after scattering, Ensemble Monte carlo simulation, Examples of device simulation using particles approach

UNIT 3Particle and Continuum Methods for properties of materials 10 Hrs.

Introduction, Basic molecular dynamics, Property calculations, Modeling chemical interactions,

Application to modelling brittle materials, Theory of reactive potentials, Reactive potentials and applications for material properties, Simulating fracture and crack propagation in materials using chemical interation methods and reactive potential methods.

UNIT 4Quantum Mechanical Methods **10 Hrs.**

Review of Quantum Mechanics, From many-body to single-particle: Quantum modeling of molecules, Application of quantum mechanics to solar thermal fuels, QM modeling for solar thermal fuels and H-storage, Atoms to solids,Quantum modeling of solids: Basic properties, Some Advanced properties of materials at atomistic regime. Applications to photovoltaics.

Max. <40> Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 - Theunderstanding of the importance of Modeling and Simulation in Science and Engineering.

CO2 –The understanding of the basics for simulation of charge carrier transport by deterministic approach.

CO3 –The understanding of the basics for simulation of charge carrier transport by probabilistic approach.

CO4 –The understanding of the methods of chemical interaction and reactive potential methods to simulate bulk properties of materials.

CO5 –The understanding of the quantum mechanical approaches to modelling and simulation.

CO6 –The understand in of the advanced modelling and simulation methods in the atomistic regime.

TEXT/REFERENCE BOOKS

1. The Physics of Semiconductors, Kevin F. Brennan, Cambridge University Press
2. Introduction to materials modeling and simulation, Richard LeSar, Los Alamos National Laboratory, Cambridge University Press,
3. Atom to Transistor, Supriyo Dutta, Cambridge University Press
4. Lessons from Nanoelectronics: New perspective to transport, Supriyo Dutta, World Scientific.
5. Physics of Semiconductors, S. M. Sze, Cambridge
6. Structure and Properties of Materials, R. Raghavan

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**

Part A/Question: <Details> <> Marks

Part B/Question: <Details> <> Marks

SE513					Galvanic Energy Storage					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	40	25	50	25	--	--	100

COURSE OBJECTIVES

- 1. Impart concept of Basic Thermodynamics and Ionic interaction.
- 2. Interface students with the knowledge of fundamental electrochemistry.
- 3. Construction of new battery systems, characterization and performance analysis.
- 4. Understanding the working principle of Fuel cell and material innovations.
- 5. Knowledge on Capacitor, Supercapacitors, Li ion capacitors, Solid State Li ion Battery.
- 6. Design of battery pack, supercapacitor pack for various storage applications.

UNIT 1 Free energy and ionic activity **8 Hrs.**

First law, Second Law, Idea of entropy, Concept Free Energy and Chemical Potential, Theory of Ionic Interactions, Concept of Concentration and Activity in Solution, Debye-Huckel Theory and determination of activity coefficients, Extension of the theory for concentrated solution.

UNIT 2 Fundamental Electrochemistry **8 Hrs.**

Idea of electrochemical potential, Equilibrium in electrolyte solutions, Electrical Conductance in Electrolyte solutions, Theory of Ion transport, Diffusion in Electrolyte Solutions, Electrode and Their Properties, Different Kind of Galvanic Cells, Electrolytic Cells, The Electrical Double layer, Model of double layer, Concept of Double layer Capacitors.

UNIT 3 Batteries and Fuel Cell **12 Hrs.**

Nernst Equation and Electrochemical series, Application of Electrochemical Series in constructing battery, Principals of battery characterization, Lead accumulators, Alkaline Battery, Metal Hydride Batteries, Li ion Battery, Metal batteries and metal-air batteries, solid state Li ion battery, comparative studies and Fuel Cells.

UNIT 4 Supercapacitors **8 Hrs.**

Material Properties, Fabrication and Characterization of EDLCs, Comparison between EDLCs and Solid State Parallel Plate Capacitors, Super capacitors and Ultra capacitors, Li ion capacitors, characterization and performance analysis. Working principle and performance analysis of Redox Flow Battery, in particular Vanadium Redox Flow Batteries.

UNIT 5 Applications

Application of energy storage devices in different domains in the Society. **4 Hrs.**

Max. <40> Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 – Define Gibbs Free Energy, Activity and Activity coefficient of an ionic system.

CO2 – Explain Nernst Equation and electrochemical series.

CO3 – Apply concept of Electrochemical Series and construct Novel Energy Storage Devices

CO4 – Categorize various Battery systems. Compare Battery, Supercapacitor and Fuel Cell.

CO5 – Determine battery bank and supercapacitor bank for specific energy storage application.

CO6 – Construct suitable energy storage bank for pure and hybrid solar applications.

TEXT/REFERENCE BOOKS

1. Hand Book of Battery Materials, Jurgen O. Besenhard (Ed.) WILEY-VCH
2. Battery Reference Book, Third Edition, T R Crompton, Newnes.
3. Electrochemical Supercapacitors, B. E. Conway, Kluwer Academic and Plenum Publishers, 1999.
4. Gianfranco Pistoia (Eds.) - Lithium-Ion Batteries. Advances and Applications (2014)
5. Chemical Thermodynamics, Lewis and randall

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**

Part A/Question: Short question type (10) with no choice	10 Marks
Part B/Question: Analytical, Application oriented (from last 3 units 9 questions each of 10 marks)	90 Marks

SE515T					Power Plant Engineering					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	6	3	25	50	25	--	--	100

COURSE OBJECTIVES

1. Basic understanding to establish a power plant.
2. Understand the economics for power generation.
3. Define the performance characteristics and components of such power plants.
4. To provide knowledge to improve efficiency of power plant

UNIT 1 SITE SELECTION & PLANT DESIGN 12 Hrs.

Site selection, survey and shading analysis: shadow types, reducing shadow, Energy yield forecast, irradiance on module plane, performance modeling, uncertainty in energy yield prediction.

Plant Design: Technology selection, layouts, electrical design, sizing of invertors, cables, fuses and protection devices, optimizing system design and its construction Commissioning of plant: General recommendation, pre-connection acceptance testing, grid connection, post connection acceptance testing, provisional acceptance

UNIT 2 OPERATION AND MAINTENANCE; ECONOMICS AND FINANCIAL MODELING 7 Hrs.

Operation and maintenance: schedule and unscheduled maintenance, spare parts, performance monitoring evaluation and optimization, contracts

Economics and financial modeling: economics benefits and costs, (Central electricity regulatory commission) CERC cost benchmarks, financial model, power purchase agreement (PPA), renewable energy certificates (REC), risk and insurance and documentation required for Solar power plant.

UNIT 3 DC-DC CONVERTORS 7 Hrs.

String inverter, micro-inverter, Inverter topology: Single stage and multistage, invertors with transformer and without transformer, MPPT, PWM switching

UNIT 4 POWER EVACUATION 12 Hrs.

Micro grid Technology, Concept, need application and formation of micro grid, interconnection issue, protection of micro grids, integration of renewable energy sources with grid, Concepts of power quality – Introduction to IEEE/IEC and other standards related to power quality –Power quality issues, Voltage regulation, harmonics, flickers, DC current injection, grounding, unbalance grid. Network reinforcement, Transient response and fault behavior, reclosing, anti- islanding studies, power system dynamics and stability.

Max. <40> Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 – Identify the layout and various components of a power plant.

CO2 - Analyse general structure of power system.

CO3 – Apply the knowledge to outline the scenario of entire business of power plants along with performance parameters, load curves and tariff calculations

CO4 – Compare the different thermodynamic cycles to improve efficiency and to reduce pollution.

CO5 – Determine the performance characteristics of renewable energy sources.

CO6 – Compare the properties of solar cells and extend their knowledge to power plant economics and environmental hazards.

TEXT/REFERENCE BOOKS

1. Planning and Installing Photovoltaic System: A guide for Installers, Architect and Engineers, German Energy Society, Published by Earthscan.
2. Peter Gevorkian, Large-Scale Solar Power System Design, McGraw Hill Professional
3. Roger A. Messenger, Jerry Ventre, Photovoltaic systems engineering, CRC Press/Taylor & Francis, 2010
4. Charles M. Whitaker, Timothy U. Townsend, Anat Razon, Raymond M. Hudson, and Xavier Vallve, PV Systems, in: Handbook of Photovoltaic Science and Engineering, Edited by Antonio Luque and Steven Hegedus, A John Wiley and Sons, Ltd., Publication
5. Ali k., M.N. Marwali, Min Dai, "Integration of green and renewable energy in electrical power system", Willey, 2009.
6. N. Mohan, T.M. undeland & W.P. Robbins, "Power electronics: Convertor, Applications and design" John Wiley & sons, 1989.
7. Clark W. Gellings, "The smart grid: Enabling Energy Efficient and demand response" CRC press,2009

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**

Part A/Question: <Details> <> Marks

Part B/Question: <Details> <> Marks

SE516					Hybrid and Electric Vehicles					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
2	0	2	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

1. Basic understanding to hybrid electrical vehicles.
2. Understand the concept of battery energy storage system and fuel cell.
3. Define dynamic of power system.
4. To provide management knowledge for the efficient hybrid electric vehicles.

UNIT 1 HYBRID AND ELECTRIC VEHICLES &PRINCIPLES OF ELECTRIC MACHINES	**9 Hrs.**
Introduction to hybrid and electric vehicles (HEVs): Electrification and hybridization concepts, HEV architectures and classifications, Technological trends, Challenges associated with EV (such as infrastructure, impact on grid, energy storage limitations, policies etc.). **Principles of electric machines (EM):** EM fundamentals and characteristics, EM selection criteria for HEVs, EM modelling and analysis.	
UNIT 2BATTERY ENERGY STORAGE SYSTEMS & FUEL CELL VEHICLES	**13 Hrs.**
Battery energy storage systems: Battery chemistry fundamentals , Battery modelling, from cell to pack, Battery pack sizing and design issues, Battery management systems (general), Battery charging infrastructure, Battery testing practical session, Battery management systems for EV. **Fuel cell vehicles:** Fuel cell fundamentals, the fuel cell electric vehicle technology, Hydrogen generation and storage systems.	
UNIT 3 POWER ELECTRONICS AND EM CONTROL	**11 Hrs.**
Principles of power electronics and EM control: Power electronic fundamentals, Electric drives for HEVs, Electric motors control systems, Super capacitors and their integration in EV, Configuration topologies of EV design **HEV transmission and alternative energy storage systems:** HEV transmission systems (converted, dedicated), Hydraulic hybrid systems, Flywheel systems. **Hybrid and electric vehicle dynamics:** Hybrid and electric vehicle dynamics, Regenerative braking, Driverless EV. Plug-in Hybrid Electric Vehicle (PHEV), Vehicle-to-vehicle communications	
UNIT 4ENERGY MANAGEMENT IN HEVS & MODEL-BASED DEVELOPMENT OF HEV	**7 Hrs.**
Energy Management in HEVS: Energy flow modelling and calculation, Energy optimization techniques, HEV supervisory control. **Model-based development of HEV:** Modelling of a HEV and its subsystems, HEV performance measurements and system analysis, design, and sizing, Control system architecture and design of HEVs. HiL simulation, testing and validation of HEVs. **Max. <40> Hrs.**	

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 –Identify the basic component of hybrid electric vehicles

CO2–Analyse the Battery management system

CO3–Apply the knowledge of transmission in power electronic and EM control

CO4 – Compare cost and performance of actual battery pack for electric vehicle

CO5 –Determine the Transmission management in HEV

CO6 – Construct working energy store tank for mobility application

TEXT/REFERENCE BOOKS

1. Electric Vehicle Technology Explained 1st Edition by James Larminie (Author). John Lowry (Author),
2. The Electric Car Development and future of battery, hybrid and fuel-cell cars (Energy Engineering) by Mike H. Westbrook (Author),
3. Electric and Plug-In Hybrid Vehicles (Green Energy and Technology) by Bogdan OvidiuVarga, Florin Mariasiu.
4. Dan Moldovanu, CalinIclodean. Electric Vehicles: Prospects and Challenges. Tariq MuncerMolanKolhe Aisling Doyle.

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100	**Exam Duration: 3 Hrs**
Part A/Question: Short five questions (2 marks each)	10 Marks
Part B/Question: Nine questions from unit 2 (2), 3(4) and 4(3) (10 marks each)	90 Marks

SE 517					Energy Lab-2					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
0	0	4	2	4	00	00	00	50	50	100

COURSE OBJECTIVES

- Provides students a hands-on experience of testing, validating and analyzing the solar photovoltaic (PV) systems deployed outdoor and roof top.
- Emulate and realize storage based and grid connected PV systems.
- Emulate and realize PV-Wind Hybrid Generation System.
- Understand important aspects of solar thermal energy generation and storage systems.
- Create pre-feasibility study report of establishing a photovoltaic power plant and a roof-top PV system.

UNIT 1: Survey and Monitoring
Site survey; Monitoring of radiation and weather; Power quality monitoring

UNIT 2: Fabrication of thin films
Solar cell fabrication & characterization; Electrochemistry Lab: Thin film deposition, complete characterization and fabrication of PV cell. Complete cell characterization

UNIT 3: Kit based experiments in PV
Series and Parallel connection of PV Modules; Estimating the effect of Sun tracking on energy generation by solar PV modules; Efficiency measurement of standalone solar PV system; Carrier Lifetime measurements for a solar cell; Solar cell simulation using PC1D and SCAPS.

UNIT 4: PV and thermal Systems
Study of various inverter systems for renewable energy sources; Experiments using PV Emulator; Experiments on Grid Tied PV Simulator; Experiments using PV-Wind Hybrid Emulator; Characterization of thermal energy storage system

COURSE OUTCOMES
On completion of the course, student will be able to
CO1 – Identify configurations of solar energy generation systems
CO2 – Develop hands on skill on tests and interpretation of outdoor PV modules under operation
CO3 – Practice data recording and their reporting
CO4 – Analyze critical aspects in a grid connected and stand-alone PV systems
CO5 – Generate pre-feasibility study report for PV power plants and roof top systems
CO6 – Design innovative projects on solar photovoltaics

TEXT/REFERENCE BOOKS

1. Energy Lab Manual, Department of Solar Energy, PDPU

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**

Part A/Question: Performance/ Experiments/ Demonstration 50 Marks
Part B/Question: Viva, Reports, Attendance 50 Marks

SE518					Nanostructured Materials for Energy Devices (SE 518)					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	40	25	50	25	--	--	100

COURSE OBJECTIVES

- 1. To introduce the importance of Nano-length Scale
- 2. To explore the variation of material properties at nano-scale
- 3. To understand the Methods for synthesizing nano-materials and their stabilization
- 4. To utilize nano-technology for fabricating highly efficient energy devices

UNIT 1 Properties at Nano-length Scale 8 Hrs.

Emergence of nanomaterials and Nanotechnology; Recent views on the challenges of Nanotechnology; Introduction to Nano-size length scale, Variation of Physical Properties of materials at the nano-length scale, How nano-materials are important for fabricating highly efficient energy conversion and storage devices. Comparison of classical and quantum physics to explain the properties of nano-materials; Examples of application of nano-materials in various field.

UNIT 2 Preparation and Stabilization of Nano-materials 8 Hrs.

General presentation of materials in nano-length scale, Top down and Bottom Up Approaches, Importance of Surface in nano-materials, Comparison of surface and volume energy, Chemical potential as a function of surface curvature, Stabilization of nano-structured materials, Bonding in nano-particles and powders, DLVO theory.

UNIT 3 Zero, One and Two Dimensional Nano-materials 18 Hrs.

Homogeneous nucleation and subsequent growth controlled by various process, Heterogeneous nucleation and growth, Kinetically confined synthesis of nano-materials, Evaporation/Dissolution – Condensation growth, VLS and SLS growth mechanism of synthesizing one dimensional materials, MBE technique, ALD technique, Lithography; Special Nanostructured Materials.

Characterization of Nanomaterials; Defects in Nanomaterials.

UNIT 4 Epitaxy and Applications **6 Hrs.**

Application of Nano-materials in Various Energy Devices with Particular Focus on Renewables.

Max. <40> Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 – What is meant by nano-materials?

CO2 – Extend the theory of bulk materials to nano-materials.

CO3 – Apply fundamentals of Nucleation and Growth to synthesize nano-materials

CO4 – Examine the importance of surface energy on the properties of nano-material

CO5 – Determine the enhanced efficiency of nano-devices of energy conversion and storage

CO6 – Develop high efficiency devices using nano-materials assembly

TEXT/REFERENCE BOOKS

1. NANOSCALE MATERIALS IN CHEMISTRY, Second Edition, Kenneth J. Klabunde and Ryan M. Richards.
2. Nano-structures and Nano-materials, Guo Zhong Cao, Imperial College Press.
3. Introduction to Nano Technology, Charles P Poole Jr., Frank J. Owens; Weily-Interscience.

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**

Part A/Question: Analytical, Application oriented (from last 3 units 10 questions each of 10 marks	100 Marks
Part B/Question: Nil	-