UNIVERSITY OF KOTA

SCHEME OF EXAMINATION

AND

COURSES OF STUDY

Department of Pure & Applied Physics
Faculty of Science

M.Tech. (Solar Energy)

First Semester Examination, December 2023
Second Semester Examination, June 2024

UNIVERSITY OF KOTA
MBS Marg, Near Kabir Circle, KOTA (Rajasthan)-324 005
INDIA

Edition: 2023

Course Structure with Distribution of Marks

Year / Semester	Serial Number, Code & Nomenclature of Paper			Duration of Exam.	Teaching Hrs/Week & Credit			Distribution of Marks			Min. Pass Marks		
	Number	Code	Nomenclature		L	P	C	Conti. Assess.	Sem. Assess.	Total Marks	Conti. Assess.	Sem. Assess.	Total Marks
I Year I Semester	1.1	SOL101	Solar Radiation and Energy Conversion	3 Hrs	4	--	4	30	70	100	12	28	40
	1.2	SOL102	Power Plant Technology	3 Hrs	4	--	4	30	70	100	12	28	40
	1.3	SOL 103	Fundamentals of Material Science and Engineering	3 Hrs	4	--	4	30	70	100	12	28	40
	1.4	SOL104	Solar Thermal Collectors	3 Hrs	4	--	4	30	70	100	12	28	40
	1.5	SOL105	Laboratory Practices	6 Hrs	--	16	8	-	200	200	--	100	100
	Total				**16**	**16**	**24**	**120**	**480**	**600**		**--**	
I Year II Semester	2.1	SOL201	Solar Photovoltaics	3 Hrs	4	--	4	30	70	100	12	28	40
	2.2	SOL202	Solar Thermal Applications	3 Hrs	4	--	4	30	70	100	12	28	40
	2.3	SOL203	Energy Audit and Management	3 Hrs	4	--	4	30	70	100	12	28	40
	2.4	SOL204	Energy Efficient Buildings	3 Hrs	4	--	4	30	70	100	12	28	40
	2.5	SOL205	Laboratory Practices	6 Hrs	--	16	8	-	200	200	--	100	100
	2.6	--	CBCS Paper		2	--	2	50	--	50	20	--	20
					16	**16**	**26**	**170**	**480**	**650**		**--**	

Objectives of the Course:

Innovation and Employability-With the growth in the power and renewable energy sector, the requirement of trained and skilled manpower has increased and will increase manifold in coming years. The successful implementation and running of the projects will depend on the availability of the skilled personnel. As government is laying impetus on utilization of solar energy through Jawaharlal Nehru National Solar Mission, many companies and many small and big projects on solar energy are coming up which require manpower trained in solar energy technologies. It is estimated that around 150 thousand jobs are there in field of solar energy utilization in India. In India very few institutes offer courses specialized in solar energy technologies, and nowhere in Rajasthan such course is being run, therefore this innovative course has been designed as Post Graduate course in Solar Energy. Solar energy technologies are varied and cover the areas ranging from heating, cooling, cooking, electricity production, drying, distillation, agricultural and industrial applications etc. So it is felt that a complete scientific course addressing the issues of solar energy technologies and power generation should be initiated and thus this course of Master of Technology in Solar Energy has been started from year 2014-15.

Programme and Course outcomes-

- Students will develop in-depth understanding of the principles of solar thermal and electrical energy systems.
- Students will gain expertise in the theoretical and practical aspects of solar energy conversion.
- Knowledge about detailed analysis of the different solar systems.
- Learners will know how to perform a technical survey of a system**.**
- Students will be trained in theory, experiments, modelling and simulation of solar systems.
- Skills related to presentation, project proposal preparation, project implementation and research paper writing will be developed.
- Learner will understand the basic requirements for the installation of any solar system and selection of the system components.
- Understanding related to undertaking research problem and offering solutions from technical, environmental, economic and societal perspectives will be enhanced.

Duration of the Course:

The duration of the course is two years which has been organized in four semesters. The first three semesters would consist of theory, laboratory work, and seminar. Fourth semester would focus on research project.

Eligibility for Admission:

B. E. / B. Tech. / M.Sc. (Physics/Math/Chemistry/Electronics/Materials Science/Nanotechnology), GEN category candidates of Rajasthan-55%; Other state-60%; SC/ST/OBC/SOBC- Minimum Passing Marks.

- The admission shall be through Merit/Written test. The written test will be conducted in case of forms more than three times the seats available. The weightage of the individual component will be calculated as given below
    - 50% of the marks obtained in the passing examination.
    - 50% of the written test
      The minimum pass marks for admission in aggregate of the above mentioned components is 40%.
- GATE qualified candidates are exempted from the entrance test for a period of two years as per the validity of the GATE score. Admission of such candidates may be made on the merit in GATE.
- Pattern of written test
    - The test will be based on objective type of questions.
    - The questions will be of scholastic aptitude type.
    - The question paper will consist of 50 questions with duration of 60 min.
    - There is no negative marking.
    - Each correct answer carries 2 marks.
- Syllabus
    - Basic mathematics (vector, matrices, determinants, calculus, trigonometry), fundamentals of computers, basic electrical and electronic circuits, fundamental thermodynamics, solar energy applications, English.

Structure of the Programme:

The programme consists of:

(i) Core and applied courses of theory as well as practical papers which are compulsory for all students.

(ii) Dissertation / Project Work / Practical training / Field work which can be done in an organization (Government, Industry, Firm, Public Enterprise, *etc.*) approved by the Department.

Attendance:

Every teaching faculty handling a course shall be responsible for the maintenance of attendance Register for candidates who have registered for the course. The teacher of the course must intimate the Head of the Department at least seven calendar days before the last instruction day in the semester about the attendance particulars of all students. Each student should earn 75% attendance in the courses of a particular semester failing which he or she will not be permitted to appear in the End-Semester Examinations. However, it shall be open to the authorities to grant exemption to a candidate who has failed to obtain the prescribed 75% attendance for valid reasons and such exemptions should not under any circumstance be granted for attendance below 65%.

Teaching Methodologies:

The classroom teaching would be through conventional lectures or power point presentations (PPT). The lecture would be such that the student should participate actively in the discussion. Student seminars would be conducted and scientific discussions would be arranged to improve their communicative skills. In the laboratory, instructions would be given for the experiments followed by demonstration and finally the students have to do the experiments individually.

Maximum Marks:

Maximum marks of a theory and practical paper shall be decided on the basis of their contact hours/credit per week. One teaching hour per week shall equal to one credit and carry 25 maximum marks and therefore, four teaching hours/credit per week shall carry 100 maximum marks for each theory paper/course. Each four contact hours per week for laboratory or practical work shall be equal to two credits per week and carry 25 maximum marks and therefore, sixteen teaching hours per week shall carry 100 maximum marks for laboratory or practical work.

Assessment Pattern:

The assessment of the students shall be divided into two parts in which first part is continuous or mid-term or internal assessment (30% weightage of the maximum marks) and second part is semester or end-term or external assessment (70% weightage of the maximum marks).

(i) Continuous / Mid-Term / Internal Assessment:

(a) The continuous or mid-term or internal assessment for each theory paper shall be taken by the faculty members in the Department during each semester. Internal assessment part is further divided in two parts of equal weightage of marks as per the details given below:

Continuous Assessment	**Modes of Assessments**		**Max. Marks**
	Collegiate (Regular) Students	**Non-collegiate (Private) Students**	
Cont. Assess-I	Written Examination	Report Writing	20
Cont. Assess-II	Seminar / Presentation / Project Report / Quiz / GD / Viva-voce	Viva-voce	10

Note: *In the Continuous/Mid-Term/Internal Assessment-I, written examination shall be of one hour duration for each theory paper and shall be taken according to the academic calendar which will be notified by the Department. Time duration for Continuous/Mid-Term/Internal Assessment-II is not allotted. It will be decided by the faculty member which will be taking second internal assessment.*

(b) For practical papers, there will not be continuous or mid-term or internal assessment. There will be only one external or end-term or semester assessment having 100% weightage of maximum marks.

(c) A student, who remains absent (defaulter) or fails or wants to improve the marks in the continuous or mid-term or internal assessment, may be permitted to appear in the desired paper(s) in same semester and one time only with the permission of the concern Head of the Department. Defaulter/improvement fee

of Rupees 250/- per paper shall be taken from such candidates. Duly forwarded application of such student by the Head of the Department, who may permit the such candidates to appear in the continuous or mid-term or internal assessment after production of satisfactory evidence about the reason of his/her absence in the test(s) and deposition of the defaulter/improvement fee, shall be sent to the concerned teacher to take the continuous or mid-term or internal assessment of such candidates. A record of such candidates shall be kept in the Department.

(d) Regular attendance of the student shall be considered in the internal assessment. Marks (equal to 10% of internal assessment) may be given to the student(s) for regularity who is/are taken classes regularly. If the attendance/regularity factor is similar for all the students, then weightage marks for regularity may be merged in the weightage of second internal assessment (seminar / presentation / assignment / dissertation / quiz / group discussion / viva-voce, *etc.*).

(e) Paper wise consolidated marks for each theory paper and dissertation / seminar (*i.e.* total marks obtained during various modes of internal assessment) obtained by the students (out of the 30% weightage of the maximum marks of the each paper) shall be forwarded by the Head of the Department (in two copies) to the Controller of Examinations of the University within a week from the date of last internal assessment test for incorporation in the tabulation register.

(f) The consolidated marks obtained by the students be also made known to them before being communicated by the concerned Head of the Department to the University for final incorporation in the tabulation register. If any discrepancies are discovered or pointed out by the students, the same shall be looked into by the concerned faculty member and corrections made, wherever necessary. The decision of the Head of the Department before the communication of marks to the University shall be final. No corrections shall be made in the internal assessment marks after the declaration of the result by the University.

(g) Consolidated marks of internal assessment obtained out of the 30% weightage of maximum marks of each theory paper which will be communicated to the University shall be in whole number and not in fraction. Marks awarded for the various internal assessments in each paper shall be added up and then round off to the next whole number to avoid any fraction.

(h) All test copies and other material related to the internal assessment shall also be sent to the Controller of Examinations of the University to keep in record as per the University guidelines.

(i) The concerned Head of the Department shall be responsible for proper conduct of internal assessment tests and for communication of the consolidated marks to the University within the prescribed time.

(j) The Head of the Department shall keep a record of the marks and also notify the same to the candidates immediately so that if any candidate is not satisfied with the award in any test or seasonal work, he / she should represent the matter to the higher authority.

(ii) Semester / End-Term / External Assessment:

(a) The semester or end-term or external assessment (70% weightage of the maximum marks) shall be 03 hours duration to each theory paper and 06 hours duration for each practical paper and shall be taken by the University at the end of each semester.

(b) The syllabus for each theory paper is divided into five independent units.

Question Paper Pattern:

(A) Continuous / Mid-Term / Internal Assessment:

30% weightage of Maximum Marks (30 Marks out of 100 Maximum Marks).

(i) Continuous / Mid-Term / Internal Assessment-I (Max. Marks: 20):

Department of .....
University / College : .....
Address .....

First Internal Assessment Test 20… - 20….
(Written Examination)

Name of Class/Course :	Max. Marks : 20 Marks
Name of Semester :	Duration of Exam. : 1.00 Hr
No. & Name of Paper :	Date of Exam. :

Q. No. 1. …… 05 Marks
or
……

Q. No. 2. …… 05 Marks
or
……

Q. No. 3. …… 05 Marks
or
……

Q. No. 4. …… 05 Marks
or
……

(ii) Continuous / Mid-Term / Internal Assessment-II (Max. Marks: 10):

Department of .....
University / College: .....
Address .....

Second Internal Assessment Test 20… - 20….
(Seminar / Presentation / Project Report / Quiz / GD / Viva-voce)

Name of Class/Course:	Max. Marks : 10 Marks
Name of Semester :	Mode of Assessment:
No. & Name of Paper:	Date of Assessment:

Format for Compilation of Marks/Awards of Continuous/Mid-Term/Internal Assessment-I & II

Department of .....
University / College: .....
Address .....

Name of Class/Course: .....
Name of Semester : .....
No. & Name of Paper: .....
Max. Marks : .....

S. No.	Name of Student	Father's Name	Marks Obtained			
			Internal Assess. - I	Internal Assess. - II	Total Marks (In Figure)	Total Marks (In Words)
1.						

Name & Signature of the Faculty Member

(B) Semester / End-Term / External / Assessment:

70% weightage of Maximum Marks (70 Marks out of 100 Maximum Marks).

Question Paper Pattern for Semester Examination

Duration of Examination: 3 Hours **Max. Marks: 70**

Note: *The syllabus is divided into five independent units and question paper will be divided into following two sections:*

- ***Section-A*** *will carry one compulsory question comprising 10 short answer type questions (answer about in 10-20 words) by taking two questions from each unit with no internal choice. Each short answer type question will have 2 marks and hence Section-A will carry total 20 marks.*
- ***Section-B*** *will carry 50 marks equally divided into five long answer type questions (answer about in 400-500 words) with one question from each unit with internal choice (another question will be given in option or question may be divided in to sub-divisions). Paper setter shall be advised to set one question from each unit along with one option of each question and students are instructed to attempt total five questions by selecting one question from each unit. Each long answer type question will have 10 marks and hence Section-B will carry total 50 marks.*

Section-A

Q. No. 1: Comprising 10 Short Answer Type Questions

Unit-I

(i) …… 02 Marks
(ii) …… 02 Marks

Unit-II

(iii) …… 02 Marks
(iv) …… 02 Marks

Unit-III

(v) …… 02 Marks
(vi) …… 02 Marks

Unit-IV

(vii) …… 02 Marks
(viii) …… 02 Marks

Unit-V

(ix) …… 02 Marks
(x) …… 02 Marks

Section-B

Unit-I

Q. No. 2: …….. 10 Marks

Or

……

Unit-II

Q. No. 3: …….. 10 Marks

Or

……

Unit-III

Q. No. 4: …….. 10 Marks

Or

……

Unit-IV

Q. No. 5: …….. 10 Marks

Or

……

Unit-V

Q. No. 6: …….. 10 Marks

Or

……

Practical Examinations:

Continuous / Mid-Term / Internal Assessment:

Not applicable in Practical Examinations.

Semester / End-Term / External Assessment:

Duration of Exam: 6 Hours **Maximum Marks: 200**

S. No.	Name of Exercise	Marks
1.	Exercise No. 1	70
2.	Exercise No. 2	70
3.	Viva-voce	40
4.	Practical Record	20
	Total Marks	**200**

Minimum Pass Marks and Rules regarding Determination of Results:

Each semester shall be regarded as a unit for working out the result of the candidates. The result of each semester examination shall be worked out separately (even if he/she has appeared at the paper of the lower semester along with the papers of higher semester) in accordance with the following conditions:

a) The candidate shall be declared as pass in a semester examination, if he/she secures at least 40% marks in each theory paper separately in continuous/internal and semester / external examinations and 50% marks in each practical paper/project/dissertation with 40% aggregate marks in that semester.

b) A candidate declared as fail/absent in one or more papers at any odd semester examination shall be permitted to take admission in the next higher semester (even semester) of the same academic session.

c) A candidate may be promoted in the next academic session (odd semester), if he/she has cleared collectively at least 50% of the papers of both semesters of previous academic session. The candidate who does not fulfill the above condition will remain as an ex-student and will re-appear in the due papers' examinations along with next odd/even semester examinations.

d) If any student who is provisionally admitted in higher odd semester but could not secure prescribed minimum marks in previous semesters will be treated as ex-student and his/her admission fee will be carry forwarded to the next odd semester of forthcoming academic session.

e) If a candidate, who is declared as pass, wants to improve his/her performance in the theory papers of just previous semester, he/she may re-appear only one time in these theory papers in next odd/even semester examinations.

f) Candidate shall not be permitted to re-appear or improve the marks obtained in the external examination of practical/dissertation in any condition.

g) If the number of papers prescribed in a semester examination is an odd number, it shall be increased by one for the purpose of reckoning 50% of the papers for considering the student pass/fail.

h) A candidate may be given only two additional chances for passing the semester thus maximum tenure for completing for three years undergraduate programme up to five years and so on.

i) The grace marks scheme shall be applicable as per the University norms.

Classification of Successful Candidates:

The classification of successful candidates after last semester examination shall be as under:

Description of Marks Obtained	Division / Result
• 75% and above marks in a paper.	Distinction in that paper.
• A candidate who has secured aggregate 60% and above marks	First Division
• A candidate who has secured aggregate 50% and above but less than 60% marks	Second Division
• A candidate who has secured aggregate 40% and above but less than 50% marks	Pass

Syllabus- Semester I

SOL 101- Solar Radiation and Energy Conversion

UNIT I

Energy Units and Conversion- energy units- Mtoe, ktoe, BTU, kWh, GJ, calorie; comparison of heat of combustion and energy-mass density of different fuels-Crude Oil, coal, gasoline, diesel, natural gas (GJ/kg, GJ/m^3, kg/GJ, m^3/GJ), efficiency of energy conversion, World energy scenario, Indian energy scenario, Energy Sankey diagram, environmental aspects of energy utilization- green house effect, global warming. Renewable energy resources and their importance, basic physics of the Sun's energy, Electromagnetic spectrum, Solar spectrum , basic laws of radiation-Planck's law, Wien's displacement law, Stefan's Boltzmann equation, solar constant, variation of extraterrestrial radiation.

UNIT II

Air mass, irradiance, solar insolation, Solar radiation on the earth surface- beam, diffuse, albedo and global solar radiation, depletion of solar radiation - Absorption, scattering, atmospheric attenuation. Measurement of solar radiation – Pyranometer, pyrheliometer, Sunshine recorder, albedometer. Solar radiation geometry –declination angle, hour angle, tilt angle, surface azimuth angle, latitude angle, solar incidence angle, solar azimuth angle. Calculation of angle of incidence - Surface facing due south, horizontal, inclined surface and vertical surface.

UNIT III

Solar time or Local apparent time (LAT), equation of time (E) correction. Sunrise, sunset, solar day length, tilt factors for beam, diffuse and reflected radiation, calculation of total solar radiation on horizontal and tilted surfaces. Estimation of average and clear sky radiation, beam and diffuse components of hourly, daily and monthly radiation, radiation on sloped surfaces- isotropic and anisotropic sky, introduction to some empirical correlations (Angstrom, Page, Klein, Gopinath, Liu and Jordan) and ASHRAE model for solar radiation calculation, effects of receiving tilt and surface orientation, utilizability, generalized utilizability and daily utilizability. Need and importance of tracking solar systems.

UNIT IV

Introduction to solar thermal energy conversion-basics of conversion of solar radiation to thermal energy, property of glass and green house effect, principle and applications of solar thermal energy in solar devices- solar cookers- hot box, parabolic, indirect type; solar dryers –direct and indirect type, passive and active type, solar distillation stills, solar water heaters-

natural circulation (thermosyphon), forced circulation, introduction to solar thermal power generation.

UNIT V

Introduction to Solar Photovoltaics- solar radiation to electrical energy conversion, semiconductors, p-n junction, photovoltaic effect, photovoltaic cell, current-voltage characteristics, solar cell equivalent circuit, fill factor, efficiency, power curve, maximum power point, effect of irradiation and temperature on solar cell outputs, factors responsible for optical, recombination and ohmic losses, techniques and measures for minimization of losses, solar module, series and parallel combination, introduction to balance of system-charge controller, batteries and inverters.

REFERENCE BOOKS

1. Foster R., Ghassemi M., Cota A., "Solar Energy", CRC Press, 2010.

2. Duffie J.A., Beckman W.A. "Solar Engineering of Thermal Processes", 3rd ed., Wiley, 2006.

3. De Vos, A., "Thermodynamics of Solar Energy Conversion", WileyVCH, 2008.

4. Garg H.P., Prakash J., "Solar Energy Fundamentals and Applications", Tata McGraw-Hill, 2005.

5. Kalogirou S., "Solar Energy Engineering", Processes and Systems, Elsevier, 2009.

6. Petela, R., "Engineering Thermodynamics of Thermal Radiation for Solar Power", McGraw-Hill Co., 2010.

7. Yogi Goswami D., Frank Kreith, Jan F. Kreider, "Principles of Solar Engineering", Second Edition, Taylor & Francis, 2003.

8. Andrews J., Jelley N., "Energy Science", Oxford University Press, 2010.

9. Sukhatme S.P., Solar Energy: Principles of Thermal Collection and Storage, Tata McGraw Hill Pub., New Delhi

SOL102- Power Plant Technology

UNIT I

Power and energy, Thermodynamic cycles – Importance of thermodynamic cycles and their use in power plants, Carnot cycle, simple Rankine cycle, modified Rankine cycle, Brayton cycle, Stirling cycle , Binary cycles, Combined cycles, concept of reheat, regeneration and supercritical.

UNIT II

Introduction to power generation. Base load, seasonal load, peak load, capacity, Load duration curves, demand management or load shifting, location of power plants, types of

power plants, Power plant economics and selection. Effect of plant type on: costs, rates, fixed elements, energy elements, customer elements, and investor's profit; depreciation and replacement. Economics in plant selection, LCOE-Levelized cost of energy, mitigation costs in energy systems.

UNIT III

Coal, Diesel and Gas Power Plants: General layout of coal based steam power plant, Power plant boilers including critical and super critical boilers. Fluidized bed boilers, boilers mountings and accessories, Different systems such as coal handling system, pulverisers and coal burners, combustion system, draft, ash handling system, Dust collection system, Feed water treatment and condenser and cooling towers and cooling ponds, Turbine auxiliary systems such as governing, feed heating, reheating, flange heating and gland leakage. Operation and maintenance of steam power plant, heat balance and efficiency, Site selection of a steam power plant. General layout and fundamentals of Diesel and Gas Turbine power plants.

UNIT IV

Hydroelectric and Wind Power Plants: Classification of hydroelectric power plants (HEPP), Principle and layout of HEPP, Types of turbine- Pelton, Francis, Kaplan, Propeller, Bulb turbines, Energy conversion and losses.

Physical principles for conversion of kinetic energy of wind to electricity, lift and drag forces, horizontal and vertical axis wind turbines, maximum theoretical efficiency of horizontal wind turbine-Betz limit, technical description of generation system, energy conversion, losses, characteristic power curve, cut in speed, cut out speed, rated power, power control-pitch and stall.

UNIT V

Nuclear Fission Power Plants: Nuclear fission reaction, critical energy of fission, fissile, fertile and fissionable materials, fission products, fission neutrons, energy released in fission, general layout and subsystems of nuclear power plants, Boiling Water Reactor (BWR), Pressurized Water Reactor (PWR), CANDU Reactor, Pressurized Heavy Water Reactor (PHWR), Fast Breeder Reactors (FBR), gas cooled and liquid metal cooled reactors, safety measures for nuclear power plants.

REFERENCE BOOKS

1. P. K. Nag "Power Plant Engineering", Tata McGraw Hill.

2. S. C. Arora and S. Domkundwar "A Course in Power Plant Engineering", Dhanpatrai & Sons.

3. M. M. El-Wakil "Power Plant Technology", Mc Graw Hill

4. R. K. Rajput "Power Plant Engineering", Laxmi Publications.

5. Black and Veatch "Power Plant Engineering", Springer.

SOL103- Fundamentals of Material Science and Engineering

UNIT I

Electronic and atomic structures, atomic bonding in solids, structure of metals and ceramics, density computations, silicates, fullerenes, polymorphism, allotropy, polycrystalline and non-crystalline materials. Polymeric structures, molecular configuration of polymers, thermosetting and thermoplastic polymers, copolymers, polymer crystallinity, semiconductors, imperfections in solids.

UNIT II

Diffusion mechanisms, factors affecting diffusion, diffusion in ionic and polymeric materials, phase diagrams, solubility limit, phase, microstructure, phase equilibria, Unary phase diagram, Binary phase diagram, alloys, phase transformations, kinetics, metastable and equilibrium states.

UNIT III

Mechanical properties of metals, concepts of stress and strain, Hooke's law, tension, compression and shear. Stress-strain diagram and thermal stresses. Elasticity in metals and polymers, plastic deformation, yield stress, shear strength, strengthening mechanisms, effect of temperature, fracture behavior of various materials and failure of metals.

UNIT IV

Electrical properties of metals, ionic materials, semiconductors and polymers, dielectrics, dielectric strength, ferroelectricity, piezoelectricity, optical properties, light interaction with solids, atomic and electronic interactions, optical properties of metals, optical properties of non-metals, applications of optical properties- luminescence, photoconductivity, lasers, optical fibers.

UNIT V

Thermal properties, thermal expansion, heat capacity, thermal conductivity, thermal stresses, magnetic properties, diamagnetism, paramagnetism, ferromagnetism, antiferromagnetism and ferrimagnetism, domains and hysteresis, soft and hard magnetic materials, superconductivity.

REFERENCE BOOKS

1. William D. Callister "Fundamentals of Materials Science and Engineering", John Wiley & Sons, New York.
2. Rose, R.M., Shepard L.A., and. Wulff, J. 'The Structure and Properties of Materials" Wiley Eastern Ltd.
3. Sheckel ford J., F. Muralidham M.K., "Introduction to Materials Science for Engineers", 6thedition, Pearson, 2007.
4. Murr L.E., "Solar Material Science" , Academic Press.
4. RaghavanV., "Materials Science and Engineering", Prentice-Hall India, 2007.
5. Askeland D.R., "Science and Engineering of Materials", 4thedition, Thomson, 2003.
6. Ramamrutam S., "Strength of Materials", 16thedition, Danpat Rai Publications, 2010.

SOL104- Solar Thermal Collectors

UNIT I

Fundamentals of Heat Transfer- modes of heat transfer- conduction, convection and radiation, radiation intensity and flux, infrared radiation exchange between gray surfaces, sky radiation, radiation heat transfer coefficient, natural convection between flat parallel plates, convection suppression, internal flow, wind convection coefficients.

UNIT II

Radiation characteristics of opaque materials- absorptance, emittance and reflectance, calculation of absorptance and emittance, measurement of surface radiation properties, selective surfaces, mechanisms of selectivity, optimum properties, angular dependence of solar absorptance, absorptance of cavity receivers, specularly reflecting surfaces.

UNIT III

Radiation transmission through glazing-reflection of radiation, absorption by glazing, optical properties of cover systems, transmittance for diffuse radiation, transmittance-absorptance product and its angular dependence, spectral dependence of transmittance, effects of surface layers on transmittance, absorbed solar radiation.

UNIT IV

Flat Plate Collectors- basic components of flat plate collectors, basic energy balance equation, temperature distribution, collector overall heat loss coefficient, collector efficiency factor, collector heat removal factor, critical radiation level, collector tilt and orientation,

mean fluid and plate temperatures, effective transmittance- absorptance product, effect of dust and shading, testing of collector performance.

UNIT V

Concentrating collector configurations, concentration ratio, acceptance angle, intercept factor, classification, imaging and non-imaging concentrating collectors, reflecting and refracting concentrating collectors, factors affecting thermal and optical performance of concentrating collectors, cylindrical parabolic collector, compound parabolic collector, paraboloid dish, central receiver systems, concept of incidence angle modifier.

REFERENCE BOOKS

1. Artur V.Kilian., "Solar Collectors: Energy Conservation, Design and Applications", Nova Science Publishers Incorporated, 2009.
2. Soteris.A.Kalogiru., "Solar Energy Engineering: Processes and systems", 1st edition, Academic press, 2009.
3. J.K.Sukhatme, Suhas P.Sukhatme., "Solar energy: Principles of thermal collection and storage", Tata McGraw Hill publishing Co. Ltd, 8th edition, 2008.
4. Duffie, J. A. & W. A. Beckman., "Solar Engineering of Thermal Processes", 3rd edition, John Wiley & Sons, Inc., 2006.
5. H.P.Garg, J.Prakash., "Solar energy fundamentals and applications", Tata McGraw Hill publishing Co. Ltd, 2006.
6. D.Yogi Goswami, Frank Kreith, Jan F.Kreider., "Principle of solar engineering", 2nd edition, Taylor and Francis, 2nd edition, 2003.
7. G.N.Tiwari., "Solar energy: Fundamentals, Design, Modeling and Applications", CRC Press Inc., 2002.

SOL105-Laboratory Practices

1) To calculate the solar azimuthal angle for solar radiation with solar time (8:00 a.m. to 4:00 p.m.) for 21 March, 21 June and 21 December and plot the results.
2) To calculate the angle of incidence of solar radiation in degree at solar noon for different days (at an interval of 20 days) of a year at surface inclined at 0°, 45° and 90° facing towards south (surface azimuth angle = 0°) and to plot the results.
3) To study the V-I characteristic of solar cell and to calculate the fill factor of the solar cell.
4) Study empirical relations for estimation of solar radiation and compare it with experimental data.

5) To study solar water heater and determine its efficiency.

6) To study solar hot box cooker and determine the figures of merit.

7) To determine the absorption coefficient of a liquid or solution (water, $KMnO_4$) with the help of a photo voltaic cell.

8) To study the Hall effect in Semiconductor and determination of allied parameters.

9) To find the Band gap of given semiconductor material with the help of Four Probe method.

10) Study of solar parabolic cooker.

11) Study of solar radiation through pyranometer and pryheliometer.

12) Study of Fresnel lens collector.

13) Evaluation of different parameters in the thermosyphonic mode of flow with fixed input parameters for solar thermal water heater.

14) Evaluation of different parameters in the forced mode of flow with fixed input parameters for solar thermal water heater.

15) Study of solar radiation through albedometer

16) Any other equivalent and relevant practical

Semester II

SOL-201- Solar Photovoltaics

UNIT I

Silicon Solar Cell Manufacturing: Basic structure of a solar cell, types and classification of solar cells. Silicon solar cells- production process of single crystalline silicon cells- refining silicon, metallurgical grade silicon, production of electronic grade silicon, production of Si wafers, Czochralski and Float Zone processes, multi crystalline silicon ingots, wafer dicing: ID and wire sawing, Si sheets, solar grade silicon, processes and process flow of commercial Si solar cell technology: cleaning and texturing, PN junction formation, antireflecting coating and surface passivation, metal contacts. Optical, ohmic and recombination losses in solar cells, measures for improving efficiency, High efficiency solar cells fabrication process flow.

UNIT II

Advances/Other Solar Cell Technologies: Difference between thick and thin film solar cells, relative advantages and disadvantages of both technologies. Materials for thin film technologies, thin film deposition techniques, common features of thin film technologies, Amorphous silicon solar cells, cadmium telluride solar cell technology, Chalcopyrite (CIGS) solar cell technology. thin film Si solar cells. Organic and Dye synthesized solar cells. Thermo-photovoltaics, Multijunction solar cells, Pervoskite solar cells,

UNIT III

PV Module Fabrication and Performance: Solar cells combination, PV module, panel and array, series and parallel connection of solar cells, design and structure of solar PV modules: number of solar cells, wattage, fabrication and packing density, I-V characteristics of a PV module, power output, maximum power point, short circuit current, open circuit voltage, efficiency, fill factor, mismatch in series connection: hot spots and bypass diode, mismatch in parallel connection, placing of bypass and blocking diodes, effect of irradiation and temperature on performance of PV module.

UNIT IV

Classification of PV System and Components: Classification- Central power station system, distributed PV system, stand alone PV system, grid interactive PV system, Building – integrated PV system, small system for consumer applications, hybrid solar PV system, concentrator solar photovoltaic. System components-PV arrays, inverters, batteries, charge controls, net power meters.

UNIT V

PV System Design and Applications: Design of solar PV lantern, stand alone PV system-Home lighting and other appliances, solar water pumping systems, grid-interacting systems, stand alone devices for distributed power supply in remote and rural areas, solar cars, aircraft, space solar power satellites, introduction to Floatavoltaics and agrivoltaics, Socioeconomics and environmental merits of photovoltaic systems.

REFERENCE BOOKS

1. Chetan Singh Solanki., Solar Photovoltaic: Fundamentals,Technologies and Application, PHL Learning Pvt Ltd., 2009.
2. Jha A.R.,Solar Cell Technology and Applications, CRC press, 2010.
3. John R.Balfour, Michael L. Shaw, Sharlave Jarosek., Introduction to Photovoltaic, Jones & Bartlett Publishers, Burlington,2011
4. Luque A.L. and Andreev V.M., Concentrator Photovoltaic, Springer, 2007.
5. Pertain L.D.,Fraas L.M., Solar Cells and Their Applications,2nd ed.,wiley,2010.
6. S.P. Sukhatme, J.K. Nayak., Solar Energy,Tata Mcgraw Hill Education Pvt Ltd, New Delhi, 2010
7. Peter Wurel "Physics of Solar Cells", Wiley-VCH.

SOL202- Solar Thermal Applications

UNIT I

Solar water heating and cooking- active and passive water heating systems, auxiliary energy, natural and forced circulation systems, integral collector storage systems, retrofit water heaters, water heating in space heating and cooling systems, testing of solar water heaters, solar cookers-types: hot box, parabolic, Scheffler, indirect type solar cookers, community solar cooking, advantages and disadvantages of hot box solar cookers, design components, factors affecting performance, Indian and international testing procedures.

UNIT II

Solar process loads, energy storage in solar process systems, need and importance of energy storage systems, sensible, latent, phase change energy storage and thermochemical energy storage systems, solar dryers- types, direct gain, indirect gain, design components, application areas, solar distillation still- design fundamentals, basic thermal network for a basin type still, efficiency of still, practical considerations and applications.

UNIT III

Solar cooling: Fundamentals of refrigeration and air conditioning, coneptual knowledge of vapour compression and vapour absorption refrigeration cycles, solar absorption cooling-

theory and applications, advantages and limitations of solar absorption cooling systems, combined solar heating and cooling, solar desiccant cooling, ventilation and recirculation desiccant cycles, solar mechanical cooling, solar related air conditioning.

UNIT IV

Solar industrial process heat: integration of solar thermal systems with industrial processes, importance and need of solar thermal systems in industrial process applications, mechanical design considerations, economics of industrial process heat, open-circuit air heating applications, recirculating air system applications, once-through industrial water heating, recirculating industrial water heating, shallow pond water heaters.

UNIT V

Solar Thermal Power Plants: thermal conversion systems, low, medium and high temperature power generation systems, Linear concentrator based concentrating solar power system, Dish/Engine based concentrating solar thermal power, parabolic based concentrating Solar power, solar chimney power plant, central receiver power plant, solar one, solar two power plants.

REFERENCE BOOKS

1. Kalogirou S.A., “Solar Energy Engineering: Processes and Systems”,Academic Press, 2009.

2. Vogel W., Kalb H., “Large-Scale Solar Thermal Power Technologies”, Wiley-VCH, 2010.

3. Duffie J. A, Beckman W. A., “Solar Engineering of Thermal Process”, Wiley, 3rd ed. 2006.

4. Khartchenko N.V., “Green Power: Eco-Friendly Energy Engineering”, Tech Books, Delhi, 2004.

5. Goswami D.Y., Kreith F., Kreider J.F., “Principles of Solar Engineering”, 2nd ed., Taylor and Francis, 2000, Indian reprint, 2003.

6. Garg H.P., Prakash J., “Solar Energy Fundamentals and Applications”, Tata McGraw-Hill, 2005.

7. Laughton C., “Solar Domestic Water Heating”, Earthscan, 2010.

8. Yannas S., Erell E., Molina J., Roof Cooling Techniques: Design Handbook, Earthscan, 2006.

9. K.Sukhatme, Suhas P.Sukhatme., “Solar energy: Principles of thermal collection and storage”, Tata McGraw Hill publishing Co. Ltd, 8th edition, 2008.

SOL203- Energy audit and management

UNIT I

Energy, environment and climate change, role of energy conservation and energy efficiency. Energy Conservation Act- 2001, Electricity Act, Bureau of Energy Efficiency, basics of energy and its various forms, energy and exergy analysis. Energy management and audit- need, objectives, types, methodology and phases, energy auditing- need, method, instruments used and report preparation. Material and energy balance, energy action planning, financial management, project management, energy monitoring and targeting.

UNIT II

Electrical system- introduction, losses, demand side management. Electric motors- factors affecting energy efficiency and minimizing losses, compressed air system, fans and blowers, pumps and pumping systems, DG set system. Introduction to the energy performance assessment of pumps, motors, fans and blowers.

UNIT III

Fuels and combustion, boilers-performance evaluation, energy conservation and efficiency measures for boilers, steam system, efficient steam utilization and energy saving opportunities, furnaces, insulation and refractories, cooling tower. Introduction to energy performance assessment of boilers, furnaces.

UNIT IV

Importance and principles of cogeneration and waste heat recovery, heat exchangers, basic introduction to performance assessment of cogeneration and waste heat recovery. Lighting systems. Introduction to energy performance assessment of buildings and commercial establishments, energy conservation in buildings, energy efficiency measures in buildings.

UNIT V

HVAC systems, introduction to performance assessment of HVAC systems, energy conservation measures in thermal power stations, energy conservation and management measures in steel industry, cement industry and textile industry. Financial insights to the energy conservation and management measures and economic analysis.

REFERENCE BOOKS

1. Reay, D. A., “Industrial energy conservation”, Pergamon Press, 1st edition, 2003.

2. White, L. C., “Industrial Energy Management and Utilization”, Hemisphere Publishers, 2002.

3. Beggs,Clive, "Energy – Management, supply and conservation",Taylor and Francis, 2nd edition, 2009.

4. Smith, C.B., Enegy "Management Principles", Pergamon Press, 2006.

5. Hamies, "Energy Auditing and Conservation; Methods, Measurements, Management and Case study", Hemisphere, 2003.

6. Trivedi, P.R. and Jolka K.R., "Energy Management", Common Wealth Publication, 2002.

7. Study material (Vol. 1-4) by Bureau of Energy Efficiency.

SOL204- Energy Efficient Buildings

UNIT I

Thermal comfort, factors affecting thermal comfort, comfort parameters, Climatic conditions, climate zone, classification of climate zones, heat flow calculations in buildings: heat flows through walls, roof, windows etc., direct heat gains through windows. Concept of cooling load Temperature Difference (CLTD), Shading coefficient (SC), Cooling Load Factor (CLF) and Solar Heat Gain Factor (SHGF), external load, internal load, sensible and latent load, Convective gains/losses, infiltration, ventilation, gains from people, appliances etc.

UNIT II

Building heating and cooling- active methods, solar heating systems based on liquid and air heating systems, heating system parametric study, solar energy- heat pump systems, need and importance of storage systems in buildings, use of phase change storage systems in buildings, seasonal storage systems, solar and off-peak storage systems, solar air-conditioning.

UNIT III

Building heating and cooling- passive and hybrid methods, concepts of passive heating and cooling, insulation, shading, sunspace, storage walls and roofs, ventilation, evaporative and nocturnal cooling, earth–air tunnel, solar chimney, active collection-passive storage hybrid systems, heat distribution in passive buildings, passive applications.

UNIT IV

Design of passive and hybrid systems- approaches to passive design, the solar –load ratio method, unutilizability design method- direct gain and collector storage walls, hybrid systems, energy efficient buildings, overview of software packages commonly used in energy-efficient building analysis and design.

UNIT V

Energy conservation building code: Purpose and scope, administration and enforcement, building envelope, heating ventilation and air-conditioning, service water heating and pumping, lighting, electrical power, whole building performance assessment, Building integrated photovoltaic systems.

REFERENCE BOOKS

1) Duffie J.A., Beckman W.A. "Solar Engineering of Thermal Process",Wiley, 3rd ed. 2006.

2) Garg H.P., Prakash J., "Solar Energy Fundamentals and Applications", Tata McGraw-Hill, 2005.

3)Yannas S., Erell E., Molina J., Roof Cooling Techniques: Design Handbook, Earthscan, 2006.

4) K.Sukhatme, Suhas P.Sukhatme., "Solar energy: Principles of thermal collection and storage", Tata McGraw Hill publishing Co. Ltd, 8th edition, 2008.

5) Energy Simulation in Building Design – J A Clarke, Butterworth-Heinemann, Oxford.

6) Renewable Energy: M. Kaltschmit, W. Streicher, A. Wiese, Springer 2007.

7) Antonio Luque and Steven Hegedus (Eds.), "Handbook of Photovoltaic Science and Engineering", Wiley.

8) Energy Conservation Building Code- User Guide, USAID-India, 2009.

9) Energy-efficient buildings in India, Mili Majumdar (Ed.), TERI-MNRE, 2002.

10) ASHRAE handbook fundamentals 1997.

SOL 205-Laboratory Practices

1) To study the I-V and P-V characteristics of PV module with varying radiation and temperature level.

2) To study the I-V and P-V characteristics of series and parallel combination of PV modules.

3) To study the effect of variation in tilt angle on PV module power.

4) To study the effect of shading on module output power.

5) To study the working of diode as bypass diode and blocking diode.

6) To workout power flow calculations of stand-alone PV system of DC load with battery.

7) To workout power flow calculations of stand-alone PV system of AC load with battery.

8) To workout power flow calculations of stand-alone PV system of DC and AC load with battery.

9) To draw the charging and discharging characteristics of battery.

10) Study of wind parameters through anemometer.

11) To study combustion of fuels through multifuel combustion analyzer.

12) Study of energy audit instruments

13) Energy auditing of a room

14) To determine the optical band gap of a given materials either in bulk or in film form by UV-VIS-NIR spectrometer.

15) Programs in Matlab

16) Any other equivalent and relevant practical.