UNIVERSITY OF KOTA

SCHEME OF EXAMINATION

AND

COURSES OF STUDY

Department of Pure & Applied Physics
Faculty of Science

M.Tech. (Solar Energy)

First Semester (July-December, 2015)
Second Semester (January-May, 2016)

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

Edition: 2015

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 Collectors	3 Hrs	4		4	30	70	100	12	28	40
	1.5	SOL105	Laboratory Practices	6 Hrs		16	8	-	100	100	-	50	50
	Total				**16**	**16**	**24**	**120**	**380**	**500**			
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	-	50	50
					16	**16**	**24**	**120**	**380**	**500**			

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.

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) with Physics and Math at B.Sc. level

For GEN category candidates of Rajasthan-55%; Other state-60%; SC/ST/OBC/SOBC- 50%.

- The admission shall be through Merit and Written test. 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.

Scheme of Examinations:

The examination shall be divided into two parts in which first part is continuous assessment or internal assessment and second part is semester assessment or external assessment. The schemes for the internal and external examinations shall be as under:

a) The assessment of the student for theory paper shall be divided into two parts in which first part is continuous assessment or internal assessment (30% of maximum marks) and second part is semester assessment or external assessment (70% of maximum marks). For practical papers there will be only one external assessment (100% of maximum marks).

b) The internal assessment for each theory paper shall be taken by the teacher concerned in the Department during each semester. There will be two internal assessment tests each of 15% weightage, for theory papers in each semester. Each internal assessment test shall be of one hour duration for each paper and shall be taken according to academic calendar notified by the University. There will be no internal examination in the practical paper.

c) A student who remains absent (defaulter) or fails or wants to improve the marks in the internal assessment may be permitted to appear in the desired paper(s) (only one time) in the same semester with the permission of the concerned Head of the Department. A defaulter / improvement fee of Rupees 250/- per paper shall be charged from such candidates. Duly forwarded application of such candidates by the teacher concerned shall be submitted to HOD who may permit the candidate to appear in the internal assessment after depositing the defaulter/ improvement fee. A record of such candidates shall be kept in the Department.

d) The external assessment shall be of three hours duration for each theory paper and six hours duration for practical paper. The practical examination shall be taken by the panel of at least one external and one internal examiner at the end of each semester.

e) The syllabus for each theory paper is divided into five independent units and each theory question paper will be divided into three sections as mentioned below:
   - ***Section-A*** *shall have 01 compulsory question comprising 10 questions (maximum 20 words answer) taking two questions from each unit. Each question shall be of one mark and total marks of this section will be 10. This section will be compulsory in the paper.*
   - ***Section-B*** *will carry 25 marks with equally divided into five long answer type questions (answer about in 250 words) and examiners are advised to set two questions from each unit and students are instructed to attempt five questions by selecting one question from each unit.*
   - ***Section-C*** *will contain five long answer type questions. One compulsory question of 15 marks and four questions of 10 marks each. Students are instructed to attempt total three questions with one compulsory question (answer about in 500 words) of and any two more questions (answer about in 400 words) out of remaining four questions. Paper setter shall be instructed to design question paper covering from all five units.*

f) The pattern of question paper of internal and external shall be as follows:

(A) Continuous or Internal Assessment:

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

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First/Second Internal Test 20…….

Duration of Exam: 1.00 Hr **Max. Marks: 15**
Class: M.Tech (Solar Energy) **Semester:**
Subject: **Paper:**
No. of Students: **Teacher:**

Note: The question paper contains three sections as under:
Section-A : One compulsory question with 04 parts. Please give short answers in 20 words for each part.
Section-B : 02 questions to be attempted having answers approximately in 250 words.
Section-C : 01 question to be attempted having answer in about 500 words.

SECTION A

Q.1(a)		1
(b)		1
(c)		1
(d)		1
	SECTION B	
Q.2		3
Q.3		3
Q.4		3
Q.5		3
	SECTION C	
Q.6		5
Q.7		5

(B) Semester or External Assessment:

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

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

SECTION-A: 10x1=10
(Answer all questions)
(Two question from each unit with no internal choice)
Q. No. 1

(i) ……..…… **1 Mark**
(ii) ……..…… **1 Mark**
(iii) ……..…… **1 Mark**
(iv)……..…… **1 Mark**
(v)……..…… **1 Mark**
(vi)……..…… **1 Mark**
(vii)……..…… **1 Mark**
(viii)……..…… **1 Mark**
(ix)……..…… **1 Mark**
(x)……..…… **1 Mark**

SECTION-B: 5x5=25
(Answer all questions)

(One question from each unit with internal choice)
(Maximum two sub-divisions only)

Q. No. 2. . …….....……
Or
…….....……
5 Marks

Q. No. 3. …….....……
Or
…….....……...
5 Marks

Q. No. 4. …….....……
Or
…….....……
5 Marks

Q. No. 5. …….....……
Or
…….....……...
5 Marks

Q. No. 6. …….....
Or
…….....
5 Marks

SECTION-C: 1x15 + 2x10=35
(Answer any three questions including compulsory Q.No. 7)
(Maximum four sub-divisions only)

Q. No. 7. …… **15 Marks**

Q. No. 8. …… **10 Marks**

Q. No. 9. …… **10 Marks**

Q. No. 10. …… **10 Marks**

Q. No. 11. …… **10 Marks**

Distribution of Marks for Practical Examinations:

Duration of Exam: 06 Hours **Maximum Marks: 100**

S. No.	Name of Exercise	Marks
1.	Exercise No. 1	60
2.	Viva-voce	25
3.	Practical Record	15
	Total Marks	**100**

Rules regarding determination of results:

Each semester shall be regarded as a unit for working out the result of the candidates. The result of the 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 external & internal examination

and 50% marks in each practical paper and at least 50 % marks in project/dissertation with 50% 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 with 50% of the aggregate marks. The candidate who does not fulfill the above condition will remain as an ex-student and will reappear in the due papers along with next odd/even semester exams.
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, wishes to improve his/her performance in the theory papers of previous semester, he/she may re-appear only one time in these 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 the two years' postgraduate course will be limited to four years, for three years postgraduate programme up to five years and so on.
i) The grace marks scheme shall be applicable as per 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**
• 80% 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

Syllabus- Semester I

SOL 101- Solar Radiation and Energy Conversion

Unit I

World energy resources - Indian energy scenario - Environmental aspects of energy utilization- green house effect, global warming. Renewable energy resources and their importance – Solar spectrum – Electromagnetic spectrum, basic laws of radiation. Physics of the Sun, solar constant, spectral distribution and variation of extraterrestrial radiation, air mass, beam, diffuse and global solar radiation, irradiance, solar insolation. Solar energy use and its importance.

Unit II

Solar radiation on the earth surface - spectral energy distribution of solar radiation. Depletion of solar radiation - Absorption, scattering, atmospheric attenuation. Measurement of solar radiation – Pyranometer, pyrheliometer, Sunshine recorder, net radiometer, albedometer. Solar time or Local apparent time (LAT), equation of time (E). Solar radiation geometry - Earth-Sun angles – Solar angles. Calculation of angle of incidence - Surface facing due south, horizontal, inclined surface and vertical surface. Sunrise, sunset, solar day length, tilt factors, Calculation of total solar radiation on horizontal and tilted surfaces. Angles for tracking surfaces.

Unit III

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, radiation augmentation, beam radiation on moving surfaces, average radiation on sloped surfaces- isotropic and anisotropic sky, effects of receiving surface orientation, utilizability, generalized utilizability and daily utilizability.

Unit IV

Introduction to solar thermal energy conversion-basics of conversion of solar radiation to thermal energy, property of glass and green house effect, applications of solar thermal energy in solar devices- solar cookers, solar dryers, solar distillation stills, solar water heaters and 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, equivalent circuit, fill factor, efficiency, power curve, maximum power point,

effect of irradiation and temperature, losses, minimization of losses, module, 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

Thermodynamic cycles – Importance of thermodynamic cycles and their use, Carnot , simple

Rankine cycle, refines Rankine cycle, Brayton cycle, Stirling cycle , Binary cycles,

Combined cycles, reheat, regeneration and supercritical.

Unit II

Introduction to power generation. Load duration curves, location of power plants, types of power plants- Steam, hydro, diesel, gas, nuclear, biomass, solar and wind, power plant economics, Indian energy scenario-power sector.

Unit III

Steam Power Plants (SPP): Advantages and disadvantages, Components of steam power plants, Effect of variations, variation of steam condition on thermal efficiency of steam power plant. Typical layout of Steam power plants. Efficiencies in a Steam Power Plant.

Unit IV

Hydroelectric Power Plants (HEPP): Advantages and disadvantages, Classification of hydroelectric power plants, Components of HEPP, Types of turbine- Pelton, Francis, Kaplan, Propeller, Deriaz and Bulb turbines, Typical layout of HEPP, Performance of turbines and comparison. Energy conversion and losses.

Unit V

Diesel and Gas Turbine Power Plants: General layout of Diesel and Gas Turbine power plants, Performance of Diesel and Gas Turbine power plants, comparison with other types of power plants.

References

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 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, effectiveness for heat exchangers.

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, absorptance of rooms.

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, flow factor, critical radiation level, collector tilt and orientation, mean fluid and plate temperatures, effective transmittance- absorptance product, effect of dust and shading, heat capacity effects, liquid heaters, air heaters, measurements of collector performance, collector characterization and tests, practical considerations.

Unit V

Concentrating collector configurations, concentration ratio, thermal and optical performance of concentrating collectors, cylindrical absorber arrays, optical characteristics of non-imaging collectors, orientation, absorbed energy and performance of CPC collectors, linear imaging concentrators, ray trace method, incidence angle modifier, energy balance, paraboloidal concentrators, central receiver collectors, practical considerations.

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. 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 using matlab.

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 using matlab.

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, KMnO4) 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 net solar radiation through net radiometer

16) Any other equivalent and relevant practical

Semester II

SOL 201- Solar Photovoltaics

UNIT I

Semiconductors, charge carriers, carrier concentration, drift, diffusion, light absorption, recombination of carriers, solar cell design for high Isc, high Voc, high fill factor, properties of efficient solar cells, lifetime and surface recombination effects, efficiency and band gap, spectral response, parasitic resistance effects, temperature effects, efficiency limits for photovoltaic conversion.

UNIT II

Silicon, metallurgical grade silicon, semiconductor grade silicon, requirements of silicon for crystalline solar cells, solar grade silicon, bulk monocrystalline material, bulk multicrystalline silicon, wafering, silicon ribbon, crystalline silicon solar cell- manufacturing process, variations, multicrystalline cells, other industrial approaches, crystalline silicon photovoltaic modules, electrical and optical performance of modules, field performance.

UNIT III

Thin film silicon solar cells-design concepts, grain enhancement, processing considerations. High efficiency III-IV multijunction solar cells, physics of multijunction and single junction, cell configuration, computation of series connected device performance, material issues, space solar cells and arrays, photovoltaic concentrators.

UNIT IV

Amorphous silicon, design, construction ,understanding and module manufacturing of amorphous silicon solar cells. Cu(InGa)Se_2 solar cells- material properties, deposition methods, junction and device formation, device operation, manufacturing issues. Cadium Telluride solar cells and modules.

Unit V

Dye-sensitized solar cells- introduction, fabrication, new developments, approach to commercialization. Measurement and characterization of solar cells and modules- rating PV performance, current-voltage measurements, primary reference cell calibration method, uncertainty estimates, intercomparison of reference cell fabrication procedures, multijunction cell measurement procedures, cell and module I-V systems, solar simulators, spectral response measurements, module qualification and certification.

REFERENCE BOOKS

1. Chetan Singh Solanki., Solar Photovoltaic: "Fundamentals, Technologies and Application", PHI 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 Photovoltaics", Jones & Bartlett Publishers, Burlington, 2011.

4. Luque A. L. and Andreev V.M., "Concentrator Photovoltaic", Springer, 2007.

5. Partain 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 Private Limited, New Delhi, 2010.

7. Peter Wurel "Physics of Solar Cells", Wiley-VCH.

8. C. J. Winter, A. L. Sizmann, L. L. Hull, "Solar Power Plant" Springer-Verlag.

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

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 and rating of water heaters, solar cookers-types, design components, factors affecting performance, Indian and international testing procedures.

UNIT II

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

UNIT III

Solar cooling: Fundamentals of refrigeration and air conditioning, solar absorption cooling-theory and applications, combined solar heating and cooling, simulation study of solar air-conditioning, solar desiccant cooling, ventilation and recirculation desiccant cycles, solar mechanical cooling, solar related air conditioning.

Unit IV

Solar industrial process heat: integration with industrial processes, 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: low, medium and high temperature power generation systems, thermal conversion systems, Gila Bend pumping system, Luz systems, 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, lighting system, DG set system. 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. Energy Performance assessment of boilers, furnaces.

Unit IV

Cogeneration, heat exchangers, waste heat recovery, performance assessment of cogeneration and waste heat recovery, energy performance assessment of buildings and commercial establishments, energy conservation in buildings, energy efficiency measures in buildings.

Unit V

HVAC systems, performance assessment of HVAC systems, energy performance assessment of thermal power station, energy performance assessment of steel industry, cement industry and textile industry. Financial 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: Unsteady heat flows through walls, roof, windows etc. Building loss coefficients, building energy storage capacity, direct heat gains through windows. Convective gains/losses, air exchange rates, Gains from people, appliances etc. Air conditioning load calculations, estimation of heating, cooling and lighting requirements, building orientation, building conditions.

Unit II

Building heating and cooling- active methods, solar heating systems- liquid and air systems, heating system parametric study, solar energy- heat pump systems, phase change and 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.