San José State University
Mechanical Engineering Department
ME170-1, Solar Energy Engineering, Section 01, Fall 2022

Instructor: Igor Tyukhov, Ph.D.

Office Location: Zoom from 1/27 to 2/11, in person from 2/14 - 5/16

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Class Days/Time:

Section	Day	Time	Code	Location
1	Tu Th	4:30PM - 5:45PM	2244	On line and Engineering Building 301

Office Hours: To be discussed

Prerequisites: EE 98 and one of ME 109, ME 114 or CHE 190 (with a grade of 'C-' or better in each)

Course Format

Online synchronous course and in person with access to Solar Deck and PV lab at E113. It means students should attend all zoom sessions.

Faculty Web Page and MYSJSU Messaging (Optional)

Course materials such as syllabus, handouts, notes, assignment instructions, etc. can be found on my faculty web page at on Canvas Leaning Management System course login website at http://sjsu.instructure.com . You are responsible for regularly checking with the messaging system through one.SJSU (MySJSU) at https://one.sjsu.edu/ (http://my.sjsu.edu) (and using gmail: My email G Suite).

Course Description

This course will study fundamentals of solar energy photovoltaic conversion and applications, basic principles, irradiation, component and system design, operation, and economics of solar energy technologies. The course will cover solar photovoltaic systems and adjacent technologies. The solar conversion topics will include energy collection, conversion, storage, and efficiency of PV and hybrid systems. The photovoltaic topics will include latest technologies, components, loads, system design, and application economics. The course will include mini-projects with team/individual presentations made throughout the semester and outside speakers to cover selected topics.

Course Goals:

1. Understanding of basic theory and principles, involved in solar radiation, electricity generation and thermal conversion, cooling, energy storage, and utilization.
2. Analyzing of current and future photovoltaic and renewable energy technologies available to collect and utilize solar energy.
3. Understanding of application of solar energy in residential, commercial, and utility-scale markets.
4. Design of solar energy system, simulation, and economic analysis.

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

1. Use engineering fundamentals to design basic components in solar energy systems.
2. Evaluate using principles of physics and simulate performance of solar energy systems.
3. Describe how solar energy can be used for generation of electricity, and with heating and cooling systems to lower energy use in buildings.
4. Design commercially viable solar photovoltaic and hybrid systems.

Course Learning Outcomes (CLO) (Required)

Students who complete all of the course assignments, including attending lectures, preparing homework problems, reading assignments, and completing student projects, **will be able to:**

1. Understand the internal photovoltaic effect and the physical processes in solar cells.
2. Utilize physics of a p-n junction to explain the IV plot for solar cells and solar modules.
3. Label open circuit voltage, short circuit current, maximum power, and fill factor.
4. Describe how the properties of the solar cells change in series and parallel.
5. Define n-type and p-type semiconductor.
6. Describe the drift and diffusion of carriers across a solar cell structure.
7. Explain built in voltage and analyze what happens to it under different biases.
8. Calculate minority carrier lifetime and diffusion length of carriers and relate their significance to PV performance.
9. Analyze fabrication steps in a basic single crystalline Si PV device based on their importance for device performance.
10. Explain limitations on conversion rate in PV devices including the Schokley-Queisser principle.
11. Describe how a solar cell is designed to minimize loss.
12. Distinguish between first, second, and third generation PV technologies.
13. Design a PV module and array for a specific application and evaluate the limitations based on cost, location, etc.
14. Design a solar panel system and calculate its annual electricity generation.
15. Describe the concept of Balance of System.
16. Analyze and estimate costs of the installation of a photovoltaic system.
17. Discuss different incentive programs and the integration of distributed solar system in the electricity grid.
18. Analyze the modern trend of integrating PV in terrestrial infrastructure and space exploration.
19. Use practical aspects of PV for solar systems design and installation.

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

Explain and use the main PV ratings (voltage, current, MPPT, fill factor, resistance, power, energy, solar irradiance and insolation, time, AM, temperature, and frequency, STC, NOCT, INOCT).

Understand, use the main PV concepts, and manipulate formulas (nonlinear IV curve, Ohm's law, power formula, energy formula, efficiency, etc.).

Draw a diagram and scheme of a PV system with all major components labeled and their functions listed.

Identify and describe the different types of PV systems (stand-alone, grid-tied, bi-modal, etc.) and their main features.

Properly size and design a PV system for performance and safety.

Required Texts/Readings:

Textbooks

Required text book:

1. Roger A. Messenger, Amir Abtahi Photovoltaic Systems Engineering, Fourth Edition March 7, 2017 by CRC Press - 504 Pages. ISBN 9781498772778.

Recommended text books:

2. Vasilis Fthenakis and Paul A. Lynn. Electricity from Sunlight: Photovoltaic-Systems Integration and Sustainability, Second Edition, 2018 John Wiley & Sons Ltd.
3. Yogi Goswami D. Principles of Solar Engineering, Third Edition Textbook February 20, 2015 by CRC Press - 822 Pages - 284 B/W Illustrations ISBN 9781466563780.
4. Solar Engineering of Thermal Processes, Photovoltaics and Wind, 5th Edition John A. Duffie, William A. Beckman, Nathan Blair, Wiley, ISBN: 978-1-119-54028-1, March 2020.

Free electronic books:

5. Smets, Arno; Jäger, Klaus; Isabella, Olindo; van Swaaij, René; Zeman, Miro. Solar Energy: The physics and engineering of photovoltaic conversion, technologies and systems (Kindle Locations 6726-6734). UIT Cambridge Ltd.. Kindle Edition. [a free online resource].
6. Honsberg, C., and S. Bowden. Photovoltaics: Devices, Systems and Applications CD-ROM. [a free online resource: http://pveducation.org/pvcdrom].
7. Solar Energy Conversion at Nanostructured Interfaces in Nanoscience and Nanotechnologies, Eds. Valeri Kharkin, Chunli Bai, in Encyclopedia of Life Support Systems (EOLSS), Developed under the Auspices of the UNESCO, Eolss Publishers, Oxford, UK, (2013) [handouts].

Other Readings

8. Photovoltaic Systems 3rd Edition by National Joint Apprenticeship and Training Photovoltaic Laboratory: Safety, Code-Compliance, and Commercial Off-the-Shelf Equipment Peter T. Parrish April 05, 2016, CRC Press.
9. Renewable and Efficient Electric Power Systems By Gilbert M. Masters, Wiley-Interscience, 2004.
10. Solar Energy: An Introduction Michael E. Mackay, Oxford University Press, 2015, 336 pages, ISBN 978-0-19-965210-5.
11. Sukhatme, S.P., Nayak, J.K., 2008. Solar energy: principles of thermal collection and storage

Other technology requirements / equipment / material

Small demonstrations

Course Requirements and Assignments (Required)

Homework Bi-weekly homework will be assigned and collected following the lecture materials presented.

One – two projects (depending on complexity) will be assigned along the semester from 2 to 4 students.

Final Examination or Evaluation

Exams: one mid-term exam will be given in the semester plus one final exam.

Grading Information (Required)

Homework (20%), Mid-term exam (20%), Projects (20%), Final exam (40%)

The scores on your homework, exams, term project, and final examination will be combined and totaled using the weighting scheme described above. A final letter grade will be determined from your overall performance (percentage) using the following criteria:

A 100 – 93%; A- 92 – 90%; B+ 89 – 87%; B 86 – 83%; B- 82 – 80%; C+ 79 – 77%; C 76 – 72%; C- 71 – 69%; D+ 68 – 66%; D 65 – 62%; D- 61 – 59%; F <58%. Note: ME students must earn at least a grade of C- to pass the course.

Classroom Protocol

The course will be conducted as a combination of instructor presented lectures, 15 minute exercises, discussions, outside subject-expert speakers, and student project presentations distributed throughout the semester. Although the course is classified as a lecture, hands-on activities at your living place in a solar energy and virtual tours to the second floor of the Engineering building – Solar Deck (Eng278), and to the new PV Lab in E133 will be conducted to supplement the lecture material. Please turn off all phones during class. Use of laptop computers and access to internet during class exercises.

Student-Instructor Relationship

Evidently, there are many students coming from a diverse range of backgrounds and academic levels. The objective of course is to make the course as meaningful, practical useful and interesting as possible, and as challenging as appropriate, without leaving students behind or causing more experienced students to get bored. It is supposed that exciting study and acquiring specific knowledge help to use an approach one can employ towards any multidisciplinary adjacent field in which engineering, technology and humanities, policy and economics are closely entwined. Acquiring professional skill is highly transferable to other industries and solving other local and global problems. Students can specialize in content ranging from Physics, Nanotechnology, Electronics, Space and Earth Sciences, Chemistry, Computer sciences, Engineering, Mathematics and much more just choosing an individual/group projects related to clean energy wide spectrum area.

It is expected each student to do her/his part: attend and participate in lectures, practical activity and virtual field trips; actively read materials before class; attend instructor's office hours before you start falling behind, and pick a project about which you are passionate. It is expected from students a complete adherence to SJSU's code of academic conduct.

University Policies

Per University Policy S16-9, university-wide policy information relevant to all courses, such as academic integrity, accommodations, etc. will be available on Office of Graduate and Undergraduate Programs' [Syllabus Information web page](http://www.sjsu.edu/gup/syllabusinfo/) at http://www.sjsu.edu/gup/syllabusinfo/"

ME170-1, Solar Energy Engineering, Section 01, Spring 2022

TENTATIVE SCHEDULE – SPRING 2022 (Zoom and in person)

Week	Date	Topics, Readings, Assignments, Deadlines
1	1/27	Introduction, course overview, Maslow's hierarchy of needs, energy, energy units, energy conversion, renewable and nonrenewable energy, energy and population, solar energy, energy currents in the surrounding world, why photovoltaics (PV) [1, 2, 3 ch.1].
2	2/1	Global problems, multi-disciplinary approach to PV, wide spectrum tasks for PV, from local and micro to global and macro consideration, nanotechnology, Hubbert oil peak, status and prospects of PV, limitations of solar energy Activity: class discussion pro and contra of solar energy [1, 2, 3 ch.1]. Questionnaire introduction quiz.
2	2/3	The Physics of the Sun, The Solar Spectrum, Black-Body Radiation, Radiation Function Tables, Transmission of Radiation through a Medium, Sun–Earth Geometric Relationship, Solar Time and Angles [1 and 2, ch. 2]. Discussing individual/team projects.
3	2/8	Introduction to PV, photovoltaic effect, solar cell (SC) as a black box. The working principle of a solar cells, the main electrical characteristics and parameters of solar cells. Spectral sensitivity of SCs. Solar modules. [1, ch. 3; 2, ch. 9; 3, ch. 1]. Quiz.
3	2/10	Measurement of Solar Radiation [2, ch. 2, p. 99], Instruments for Measuring Solar Radiation and Sunshine, Detectors for Solar Radiation Instrumentation; [1 and 2, ch. 2].
4	2/15	PV fundamentals, semiconductor materials and zone theory [1, ch10], physics of p-n junction, contacts in semiconductor materials and p-n junction, a short history of solar cells [3, ch. 11]. Quiz.
4	2/17	Crystalline silicon solar cells [3, ch.12], thin film solar cells, third generation solar cells.
5	2/22	Losses in SCs, maximizing PV cell performance [1, ch. 10]. Quiz.
5	2/24	Manufacturing of solar cells and modules, evolution of solar cells and new technologies [1, ch. 11; 2, ch.9.3].
6	2/28	High-efficiency solar cells and main approaches to decrease losses [1, ch. 11]. Unusual design solar cells (Sliver SCs, SCs with vertical p-n-junctions [original papers]. Quiz.
6	3/1	Thermoelectric Effect or Thermoelectricity. Thermoelectric detectors and thermoelectric energy conversion. Thermo photovoltaic (TPV) systems [1, section 11.6.6, 2, section 2.7.2].
7	3/3	Introduction to PV systems [1, ch. 3; 3 ch. 17]. Quiz.
7	3/8	Balance of System Components, energy storage; demonstration: reversible fuel cell [1, ch.3 (3.10)].
8	3/10	Stand-alone power system [1, ch.7]. Presentations of projects activity.
8	3/15	Grid-connected Utility-Interactive PV Systems [1, ch.4].
9	3/17	Midterm exam

Week	Date	Topics, Readings, Assignments, Deadlines
9	3/22	Mechanical consideration. Design and installation guidelines [1, ch. 5].
10	3/24	Solar concentrators and non-imaging optics, tracking systems. Solar concentrator systems. [2, ch.3, p.164-204]. Quiz.
10	4/5	PV applications (from solar calculators to terrestrial and space solar plants), electrical cars and PV, cathodic protection systems.
11	4/7	Nanotechnology for solar cells [handouts - Solar Energy Conversion at Nanostructured Interfaces in Nanoscience and Nanotechnologies]. Quiz.
11	4/12	Combined renewable energy systems (PVT, wind, biomass, geothermal, microhydro). Alternative energy. Solar Radiation and Meteorological Data, Solar Radiation Mapping Using Satellite Data, GIS [2, p.107-112, Internet resources].
12	4/14	More on PV applications (from solar calculators to terrestrial and space solar plants), Solar Photochemical Applications, Solar disinfection of water and air [2, ch.10]. Quiz.
12	4/19	Solar thermal collectors and PVT systems [2, ch.3].
13	4/21	Solar Radiation data, Solar Radiation Mapping Using Satellite Data, GIS [2, p.107-112]. Quiz.
13	4/26	Combined renewable energy systems (PVT, wind, biomass, geothermal, microhydro).
14	4/28	More on PV applications: Solar Photochemical Applications, Solar disinfection of water and air [2, ch.10, internet resources]. Quiz.
14	5/3	Economic consideration, The Time Value of Money, Borrowing Money, Externalities [1, ch. 8]. Levelized Cost of Energy [2, p. 19].
15	5/5	Environmental Effects of Energy Sources, Ecological aspects of PV, externalities and PV, LCA, cyclic economy, material resource limitations [1, ch.9]. Presentations of projects results.
15	5/10	New ideas, topics: new materials (like shape memory materials and graphene), PV for transport (solar races, solar planes, solar boats), smart grids, Floating Solar PV Plants, Agrivoltaics, AI in solar engineering, integrating PV and REN to IoT [internet resources, solar energy and other journals, free e-books].
16	5/12	Presentations of projects (last day).
16		Final Exam (According School Schedule)

Demonstrations in the lectures: solar spinning top and mystery spinning top, Celt stone (rattle back), Crooks radiometer, drinking bird (video), thermo-electrical element, samples of solar cells (mono Si, poli Si, organic), Fresnel lens, magnifying mirror, photo-luminescent concentrator, focons (non-imaging optics), solar lights, solar calculator, samples of SC with vertical p-n-junctions, solar restore, photovolt (high voltage multifunction p-n-junctions), solar lights, solar calculator, sample of shape memory material.

In case of improving the situation with COVID viruses some lectures will be transformed to practical activity with PV lab stations.

List of recommended free software (like SMARTS https://www.nrel.gov/rredc/smarts/, NREL PVWatts calculator http://pvwatts.nrel.gov/, MODTRAN http://arm.mrcsb.com/sbdart / RETScreen Clean Energy Management Software http://www.nrcan.gc.ca/energy/software-tools/7465, System Advisor Model (SAM), NREL https://sam.nrel.gov/) will be available for student. Using such programs Matlab (Simulink), Labview, and others depending on background and major of students are welcome.

Practical hands-on activities (at your living place) are also envisaged for students who wants to acquire the real skills of designer, engineer, researcher. Try to generate ideas, do patent search – it will be discussed how to use the open patent databases like http://appft.uspto.gov/netahtml/PTO/search-bool.html .

So, this course provides for great opportunities to know physics, technology, basic things on Photovoltaics and adjacent technologies, to acquire useful and practical experience and skills in modern soft and hard ware of solar engineering taking into account their interests to be more competitive at the grooving labor market.