Bulletin Course Description:
Introduction to the basic concepts of photovoltaic solar energy conversion, including: 1. The solar resource in the context of global energy demand; 2. The operating principles and theoretical limits of photovoltaic devices; 3. Device fabrication, architecture, and primary challenges and practical limitations for the major technologies and materials used for photovoltaic devices. Students will gain knowledge of: the device physics of solar cells, the operating principles of the major commercial photovoltaic technologies, the current challenges and primary areas of research within the field of photovoltaics, and a basic understanding of the role of photovoltaics in the context of the global energy system.

Course Title: Introduction to Photovoltaics

Contribution of course to meeting the Professional Component: Engineering Science 50%, Laboratory Experience 0%, Mathematics 10%, Basic Science 20%, General Education 10%, Design Experience 10%

Spring 2018

Stony Brook University
Department of Electrical & Computer Engineering
College of Engineering and Applied Sciences
Course Title: Introduction to Photovoltaics
Course Instructor: Prof. Matthew D. Eisaman

Instructor and TA contact information:
Prof. Matthew D. Eisaman
Email: matthew.eisaman@stonybrook.edu
Work Phone: 631-632-8421
Office Location: Light Engineering, 145
Office Hours: Thursdays 11:00am - 1:00pm, and by appointment, if needed

Course Pre/co-requisites
ESE 231 (Introduction to Semiconductor Devices) or equivalent. The course assumes a basic understanding of semiconductor device physics, but critical elements to photovoltaic devices will be reviewed in this course.

LEARNING OBJECTIVES (satisfies SBC's Understand Technology (TECH) learning objective)
At the end of this course, students will (LO = Learning Outcomes for "Understand Technology"):

1. Know how to calculate the available solar energy resource at various global locations for specific photovoltaic installations (LO1)
2. Understand semiconductor physics relevant to photovoltaic devices (LO2)
3. Understand the major commercial and developing technologies for solar cells (LO2)
4. Understand advanced characterization techniques for solar cells (LO2)
5. Understand the economic and environmental issues relevant to photovoltaic systems, and know how to calculate the cost, environmental impact, and energy payback time of a photovoltaic system. (LO1 and LO2)

COURSE REQUIREMENTS
Attendance and Make Up Policy
Late work will not be accepted. Attendance at all exams is mandatory. In the case of: 1) Verifiable illness, 2) Verifiable family emergency, 3) University-sanctioned religious holiday, or 4) Participation in official University-sponsored events (for documented student athletes only), excuse must be documented on official letterhead (as appropriate) and will be verified by the instructor.

Description and schedule of Required Readings and/or Assignments.

REQUIRED TEXTBOOKS

- J. Nelson, *Physics of Solar Cells*, Imperial College Press, 2003. ISBN-13: 978-1860943492.

FREE ONLINE RESOURCES

- C. Honsberg and S. Bowden, Photovoltaics: Devices, Systems and Applications CDROM. (http://www.pveducation.org/pvcdrom)
- K. McIntosh, M. Abbott, and S. Baker-Finch, PV Lighthouse (http://www.pvlighthouse.com.au/)
- *Sunshot Vision Study*, Feb. 2012, US Dept. of Energy, Office of Energy Efficiency and Renewable Energy (EERE).

SELECTED READINGS MADE AVAILABLE ON BLACKBOARD

Book Chapters

- A. Luque and S. Hegedus, eds., *Handbook of Photovoltaic Science and Engineering, 2nd Edition*, John Wiley & Sons, Inc., 2011, ISBN: 978-0-470-72169-8.
- Gavin J. Conibeer and Arthur Willoughby, eds., *Solar Cell Materials: Developing Technologies*, John Wiley & Sons, Inc., 2014, ISBN: 978-0-470-06551-8.
- J. Poortmans and V. Arkhipov, eds., *Thin Film Solar Cells: Fabrication, Characterization, and Applications*, John Wiley & Sons, Ltd., 2006,
- D. Abou-Ras, T. Kirchartz, and U. Rau, eds., *Advanced Characterization Techniques for Thin Film Solar Cells*, Wiley-VCH Verlag GmbH & Co., 2011. ISBN: 9783527636280.
- L. Tsakalakos, *Nanotechnology for Photovoltaics*, CRC Press, 2010, ISBN-13: 978-1420076745.
- A. Rockett, *The Materials Science of Semiconductors*, Springer, 2008, ISBN 978-0-387-68650-9.

Primary literature

- V. Fthenakis, *Sustainability of photovoltaics: The case for thin-film solar cells*, Renewable and Sustainable Energy Reviews **13**, 2746–2750 (2009).
- W. Shockley and H. J. Quiesser, *Detailed Balance Limit of Efficiency of pn Junction Solar Cells*, Journal of Applied Physics **32**, 510 (1961).

ADDITIONAL RESOURCES (NOT REQUIRED):

Books

- M. Green, *Solar Cells: Operating Principles Technology (The Red Book)*, UNSW Photovoltaics, 1986. ISBN: 0858235803.
- P. Wurfel. Physics of Solar Cells: From Basic Principles to Advanced Concepts. Wiley VCH, 2009. ISBN: 9783527408573.

Periodicals and websites with up-to-date PV industry information

- Greentech media: http://www.greentechmedia.com/channel/solar
    - News, research, and analysis in the business-to-business solar market
- Solar Industry Magazine: http://www.solarindustrymag.com/
    - Analyzes the details that help professionals navigate the solar market
- Solar Power World: http://www.solarpowerworldonline.com/
    - For executives, managers, engineers, installers and technical professionals involved in the design, manufacturing, development, and installation of solar power projects
- Photon International: http://www.photon.info/photon_home_en.photon
    - Photovoltaic research and development, economy, new projects
- PV Magazine: http://www.pv-magazine.com/
    - Latest technological trends and market developments worldwide
- Many others: http://www.pvresources.com/Periodicals/English.aspx

SYLLABUS

Week	Dates	Topics	Text Readings: **Required** (Optional) BB = Posted to Blackboard
Week 1	1/22	1. What is a photovoltaic (PV) device? 2. Why solar? PV in the context of global energy demand and climate change; 3. History of PV development and deployment 4. Overview of PV technologies The solar resource: Spectra, insolation, diffuse vs. direct, atmospheric absorption (AM0 and. AM1.5), metrics for specifying system output, land area requirements	**Nelson 1,2** **Honsberg 1,2** **Sunshot Vision Study, Executive Summary and Ch. 1 (BB)** **Sunshot 2030 Goals White Paper (BB)** (Green 1)
Week 2	1/29	Review of semiconductor physics	**Nelson 3** **Honsberg 3.1** (Green 2)
Week 3	2/5	Semiconductor equations, light absorption and charge generation, recombination	**Nelson 4** Honsberg 3.2-3.4 (Green 3)
Week 4	2/12	Analysis of pn junctions, depletion approximation, solution of semiconductor equations in depletion approximation, derivation of ideal diode law, solar cell performance output parameters	**Nelson 5,6** **Honsberg 3.5-3.6, 4.1-4.2** (Green 4)
Week 5	2/19	Ideal efficiency limits, Practical sources of loss, equivalent circuit model, characterizing solar cell performance	**Honsberg 4.2-4.4, 8** **Nelson 10.1-10.3, Review Nelson 2** (Green 5)
Week 6	2/26	First half of class: Improving efficiency by reducing optical losses: texturing, anti-reflection coatings, light trapping, photon recycling, concentrating PV (CPV) Second half of class: Improving efficiency by reducing optical losses (cont'd)	**Nelson 9** **Honsberg 5.1** (Green 8.7-8.9)
Week 7	3/5	First half of class: **MIDTERM** Second half of class: Improving efficiency by reducing electrical losses, Reducing recombination and resistance via doping profiles and top contact design	**Honsberg 5.2-5.4** (Green 8.1-8.6)
SPRING BREAK	3/12	**SPRING BREAK**	**SPRING BREAK**

Week 8	3/19	1. Overview of commercial technologies 2. Commercial Technologies 1, Crystalline Si (c-Si).	**Same as week 7** **Honsberg 5.2-5.4** (Green 8.1-8.6) **Week 8** **Nelson 7** **Honsberg 6,7** **Luque 7 (BB)**
Week 9	3/26	1. Commercial Technologies 1, Crystalline Si (c-Si) continued.	**Same as Week 8** **Nelson 7** **Honsberg 6,7** **Luque 7 (BB)**
Week 10	4/2	2. Commercial Technologies 2, Thin film Si (amorphous and crystalline)	**Nelson 8.1-8.5** **Luque 11,12 (BB)**
Week 11	4/9	Commercial Technologies 3: CdTe and CIGS	**Nelson 8.6-8.9** **Luque 13,14 (BB)**
Week 12	4/16	Emerging Technologies: organic PV (OPV) perovskites, CZTS	**Emerging Technologies** **Luque 16 (BB)**
Week 13	4/23	First half: Breaking the single-junction limit – multijunction cells and hot carriers, multiple exciton generation Second half: Measurement and characterization of solar cells	**Breaking single-junction limit** **Nelson 10** **Luque 8 (BB)** **Characterization** **Honsberg 8** **Selections from Abou-Ras (BB)**
Week 14	4/30	1. Economics of PV; Environmental impact and benefit of PV: Life cycle analysis, energy pay back timing, resource extraction and limitations 2. Review of important concepts for final exam	**SunShot Vision Study (2011) (BB)** **Fthenakis Lifecycle Chapter (BB)** **Fthenakis (2009) (BB)** **NY Times article (BB)**
FINAL EXAM	**TBD**	**FINAL EXAM**	**All topics covered in course**

ASSIGNMENTS

Problem sets

There will be weekly problem sets. Problem sets will be distributed at the end of each lecture and will be **due the following lecture at the start of class**. Late problem sets **will not be accepted - no exceptions**. Please turn in what you have at the start of class.

Comprehension quizzes

At the end of every lecture, we will have a comprehension quiz on the material presented in the lecture. These quizzes are designed to require less than 5 minutes to complete, and are meant to provide feedback to the student and instructor on student comprehension.

Exams

The midterm exam will be based on all information presented up through Week 6 and will be designed to take 1.5 hours. The final exam will include all material presented in all lectures and will be designed to take 3 hours.

GRADING

The course grade will be based on the following components:

Item	Percent
Problem Sets	40
Midterm exam	20
Final exam	30
Comprehension quizzes	10

Grades are based on the following scale:

A = 93-100, A- = 90-92
B+ = 88-89, B = 83-87, B- = 80-82
C+ = 78-79, C = 73-77, C- = 70-72
D+ = 68-69, D = 63-67, F <63

Grading Policy for grad and undergrad versions are different. Midterm, final, and problem sets will contain more challenging questions that are required for graduate students but are optional (bonus points) for undergrads.

MEETING SCHEDULE

Mid-term exam: In class, week 7
Final exam: TBD

CLASS PROTOCOL

All electronic devices are to be turned off during class unless advance permission is given by the instructor. No recording of lectures of any kind (including audio and video) is allowed.

CLASS RESOURCES

Blackboard (http://blackboard.stonybrook.edu) will be used as the primary means of distribution for readings from the primary literature and submission of assignments.

If you have a physical, psychological, medical or learning disability that may impact your course work, please contact Disability Support Services, ECC (Educational Communications Center) Building, room 128, (631) 632-6748. They will determine with you what accommodations, if any, are necessary and appropriate. All information and documentation is confidential.

Students who require assistance during emergency evacuation are encouraged to discuss their needs with their professors and Disability Support Services. For procedures and information go to the following website: http://www.stonybrook.edu/ehs/fire/disabilities]

Each student must pursue his or her academic goals honestly and be personally accountable for all submitted work. Representing another person's work as your own is always wrong. Faculty are required to report any suspected instances of academic dishonesty to the Academic Judiciary. Faculty in the Health Sciences Center (School of Health Technology & Management, Nursing, Social Welfare, Dental Medicine) and School of Medicine are required to follow their school-specific procedures. For more comprehensive information on academic integrity, including categories of academic dishonesty, please refer to the academic judiciary website at http://www.stonybrook.edu/uaa/academicjudiciary/

Stony Brook University expects students to respect the rights, privileges, and property of other people. Faculty are required to report to the Office of Judicial Affairs any disruptive behavior that interrupts their ability to teach, compromises the safety of the learning environment, or inhibits students' ability to learn. Faculty in the HSC Schools and the School of Medicine are required to follow their school-specific procedures.