

EP 4X03
Introduction to Photovoltaics

Undergraduate Studies

Shockley, smockley – nanostructures, self-assembly and the promise of solar for all
Fall 2021 Course Outline

CALENDAR/COURSE DESCRIPTION

3 unit(s)

A review of photovoltaic devices including solar cell operation, characterization, manufacturing, economics and current and next generation technologies.

PRE-REQUISITES AND ANTI-REQUISITES

Prerequisite(s): One of ELECENG 2E15, MATLS 3Q03 or ENGPYS 3BA3

Antirequisite(s): None

INSTRUCTOR OFFICE HOURS AND CONTACT INFORMATION

Dr. A. Turak

JHEA 321

turaka@mcmaster.ca

ext. 23448

Office Hours:

Thursday – 12:30 pm (Zoom/Teams)

Or by appointment

TEACHING ASSISTANT OFFICE HOURS AND CONTACT INFORMATION

Paramita Bhattacharyya

bhatp14@mcmaster.ca

Office Hours:

TBD

COURSE WEBSITE/ALTERNATE METHODS OF COMMUNICATION

<http://avenue.mcmaster.ca/> (Avenue to Learn, Avenue, A2L)

Synchronous Lectures: Zoom

DM/discussions: Teams

COURSE INTENDED LEARNING OUTCOMES

By the end of this course, students should be able to:

- Differentiate between various types of solar cell technologies
- Distinguish the basic physics underlying the operation of various device architectures
- Critique chief technical challenges and critical materials issues for solar cells
- Examine the state of the art of modern solar cell technology

MATERIALS AND FEES

Required Texts:

Optional Texts:

1. "The Physics of Solar Cells" by Jenny Nelson, Imperial College Press 2003
2. "Materials Concepts for Solar Cells" by Thomas Dittrich, Imperial College Press

COURSE FORMAT AND EXPECTATIONS

This course gives an overview and introduction to photovoltaic devices, with some emphasis on the development of novel materials. The course will cover aspects of operation and design for photovoltaics, highlighting traditional, multijunction, nanoscale and excitonic device physics. The major aim of this course is to examine solar cells and understand the development of the technology; focus will also be given to novel materials and approaches: organic semiconductors, graphene and layered materials, nanowires, quantum dots, multi-exciton generation, intermediate band, etc. Through real world examples, students will be able to expand their understanding of fundamental principles of photovoltaics, while gaining exposure to cutting edge technology.

The course is organized as follows:

- Three synchronous lectures per week (available for asynchronous viewing)
- Report on PV technology
- Video presentation on PV technology
- 3-4 assignments, incorporating your chosen PV technology
- Final exam

COURSE SCHEDULE

Topic 1 Energy costs and Solar energy	What is PV? Overview of energy consumption Pollutants, toxicity LCOE, Energy pay back time
Topic 2 Photons to electrons: The sun	Total solar energy Blackbody radiator AM spectra Solar radiation Insolation Solar Position and orientation of solar panels
Topic 3 Solar Cell Basics	Photons to electrons: device measurements Photons to electrons: photovoltage and the Voc Photons to electrons: reverse saturation current, ideal Voc
Topic 4 Real Devices	Photons to electrons: away from ideality – SQ Limit and detailed balance Real devices: optical designs and losses Real devices: optical design to mitigate losses Photons to electrons: electrical losses Photons to electrons: series resistance and recombination
Topic 5 Characterization	Electrical characterization Optical characterization Characterization of anti-reflection coatings Quality of materials
Topic 6 Solar cell technologies and manufacturing	State of the art Si solar cells State of the art organic solar cells
Possible Special topics	Potential for flexibility Degradation

ASSESSMENT

Component	Weight
Assignments	15%
Presentation	35%
Report	25%
Final Exam	25%
Total	100%

ACCREDITATION LEARNING OUTCOMES

The Learning Outcomes defined in this section are measured for Accreditation purposes only and will not be directly taken into consideration in determining a student's grade in the course.

For more information on Accreditation, please visit: <https://www.engineerscanada.ca>

EQUITY, DIVERSITY, AND INCLUSION

Every registered student belongs in this course. Diversity of backgrounds and experiences is expected and welcome. You can expect your Instructor to be respectful of this diversity in all aspects of the course, and the same is expected of you.

The Department of Engineering Physics is committed to creating an environment in which students of all genders, cultures, ethnicities, races, sexual orientations, abilities, and socioeconomic backgrounds have equal access to education and are welcomed and treated fairly. If you have any concerns regarding inclusion in our Department, in particular if you or one of your peers is experiencing harassment or discrimination, you are encouraged to contact the Chair, Associate Undergraduate Chair, Academic Advisor or to contact the [Equity and Inclusion Office](#).

PHYSICAL AND MENTAL HEALTH

For a list of McMaster University's resources, please refer to the [Student Wellness Centre](#).

ACADEMIC INTEGRITY

You are expected to exhibit honesty and use ethical behaviour in all aspects of the learning process. Academic credentials you earn are rooted in principles of honesty and academic integrity. **It is your responsibility to understand what constitutes academic dishonesty.**

Academic dishonesty is to knowingly act or fail to act in a way that results or could result in unearned academic credit or advantage. This behaviour can result in serious consequences, e.g. the grade of zero on an assignment, loss of credit with a notation on the transcript (notation reads: "Grade of F assigned for academic dishonesty"), and/or suspension or expulsion from the university. For information on the various types of academic dishonesty please refer to the [Academic Integrity Policy](https://secretariat.mcmaster.ca/university-policies-procedures-guidelines/), located at <https://secretariat.mcmaster.ca/university-policies-procedures-guidelines/>

The following illustrates only three forms of academic dishonesty:

1. plagiarism, e.g. the submission of work that is not one's own or for which other credit has been obtained.
2. improper collaboration in group work.
3. copying or using unauthorized aids in tests and examinations.

AUTHENTICITY / PLAGIARISM DETECTION

Our course will use a web-based service (Turnitin.com) to reveal authenticity and ownership of student submitted work. For courses using such software, students will be expected to submit their work electronically either directly to Turnitin.com or via an online learning platform (e.g. A2L, etc.) using plagiarism detection (a service supported by Turnitin.com) so it can be checked for academic dishonesty.

Students who do not wish their work to be submitted through the plagiarism detection software must inform the Instructor before the assignment is due. No penalty will be assigned to a student who does not submit work to the plagiarism detection software. **All submitted work is subject to normal verification that standards of academic integrity have been upheld** (e.g., on-line search, other software, etc.). For more details about McMaster's use of Turnitin.com please go to www.mcmaster.ca/academicintegrity.

COURSES WITH AN ON-LINE ELEMENT

McMaster is committed to an inclusive and respectful community. These principles and expectations extend to online activities including electronic chat groups, video calls and other learning platforms.

Our course will use on-line elements (e.g. e-mail, Avenue to Learn (A2L), Zoom). Students should be aware that, when they access the electronic components of a course using these elements, private information such as first and last names, user names for the McMaster e-mail accounts, and program affiliation may become apparent to all other students in the same course. The available information is dependent on the technology used. Continuation in a course that uses on-line elements will be deemed consent to this disclosure. If you have any questions or concerns about such disclosure, please discuss this with the course instructor.

CONDUCT EXPECTATIONS

As a McMaster student, you have the right to experience, and the responsibility to demonstrate, respectful and dignified interactions within all of our living, learning and working communities. These expectations are described in the [Code of Student Rights & Responsibilities](#) (the "Code"). All students share the responsibility of maintaining a positive environment for the academic and personal growth of all McMaster community members, **whether in person or online**.

It is essential that students be mindful of their interactions online, as the Code remains in effect in virtual learning environments. The Code applies to any interactions that adversely affect, disrupt, or interfere with reasonable participation in University activities. Student disruptions or behaviours that interfere with university functions on online platforms (e.g. use of Avenue 2 Learn, Zoom for delivery), will be taken very seriously and will be investigated. Outcomes may include restriction or removal of the involved students' access to these platforms.

ACADEMIC ACCOMMODATION OF STUDENTS WITH DISABILITIES

Students with disabilities who require academic accommodation must contact [Student Accessibility Services](#) (SAS) at 905-525-9140 ext. 28652 or sas@mcmaster.ca to make arrangements with a Program Coordinator. For further information, consult McMaster University's [Academic Accommodation of Students with Disabilities](#) policy.

COURSE POLICY ON MISSED WORK, EXTENSIONS, AND LATE PENALTIES

1. It is the students' responsibility to regularly check Avenue to Learn for updates and announcements.
2. **How work is to be submitted:**
 - All submission should be submitted through dropboxes on Avenue to Learn in pdf format.
3. **Policies on missed work, extensions, and late policies**
 - Late hand-ins will be penalized by 10% for each day, except with prior permission from the instructor. Permission must be obtained at least two days in advance of the deadline to waive the hand-in penalty.
4. **Group work expectations and how group work will be evaluated**
 - Group work is permitted provided all of the contributors' names are listed on the assignment paper. The same mark will be assigned to all group members. The number of group members is limited to three (3).
5. **Participation expectations:**
 - Class participation is encouraged through the asking and answering of questions throughout the term.
 - For the video presentations, there is a peer evaluation component. Everyone is expected to watch and comment on everyone else's presentations; this will be counted as a component of your own presentation and report marks. This will also be a component of the final exam. The peer marks will be incorporated into the final mark for the presentation.
6. **Attendance requirements:**
 - Attendance at lectures is optional for this class. There will be synchronous lectures and discussion during the designated class times. Recorded lectures will be available for asynchronous viewing. Avenue to Learn forums and discussion boards will be available for asynchronous discussions.
7. **Final exam**
 - In order to pass the course, it is necessary to obtain at least 40% on the final examination. It will be a test of cumulative knowledge and test all topics covered, including questions relating to the in-class presentations of your peers.

SUBMISSION OF REQUEST FOR RELIEF FOR MISSED ACADEMIC WORK

In the event of an absence for medical or other reasons, students should review and follow the Academic Regulation in the Undergraduate Calendar "Requests for Relief for Missed Academic Term Work".

1. **Relief for missed academic work worth less than 25% of the final grade resulting from medical or personal situations lasting up to three calendar days:**
 - Use the [McMaster Student Absence Form](#) (MSAF) on-line self-reporting tool. No further documentation is required.
 - Students may submit requests for relief using the MSAF once per term.
 - An automated email will be sent to the course instructor, who will determine the appropriate relief. Students must immediately follow up with their instructors. Failure to do so may negate the opportunity for relief.
 - The MSAF cannot be used to meet a religious obligation or to celebrate an important religious holiday.
 - The MSAF cannot be used for academic work that has already been completed attempted.

- An MSAF applies only to work that is due within the period for which the MSAF applies, i.e. the 3-day period that is specified in the MSAF; however, all work due in that period can be covered by one MSAF.
 - The MSAF cannot be used to apply for relief for any final examination or its equivalent. See *Petitions for Special Consideration* above.
2. **For medical or personal situations lasting more than three calendar days, and/or for missed academic work worth 25% or more of the final grade, and/or for any request for relief in a term where the MSAF has been used previously in that term:**
- Students must report to their Faculty Office to discuss their situation and will be required to provide appropriate **supporting documentation**.
 - If warranted, the Faculty Office will approve the absence, and the instructor will determine appropriate relief.

ACADEMIC ACCOMMODATION FOR RELIGIOUS, INDIGENOUS OR SPIRITUAL OBSERVANCES (RISO)

Students requiring academic accommodation based on religious, indigenous or spiritual observances should follow the procedures set out in the [RISO](#) policy. Students should submit their request to their Faculty Office **normally within 10 working days** of the beginning of term in which they anticipate a need for accommodation or to the Registrar's Office prior to their examinations. Students should also contact their instructors as soon as possible to make alternative arrangements for classes, assignments, and tests.

COPYRIGHT AND RECORDING

Students are advised that lectures, demonstrations, performances, and any other course material provided by an instructor include copyright protected works. The Copyright Act and copyright law protect every original literary, dramatic, musical and artistic work, **including lectures** by University instructors

The recording of lectures, tutorials, or other methods of instruction may occur during a course. Recording may be done by either the instructor for the purpose of authorized distribution, or by a student for the purpose of personal study. Students should be aware that their voice and/or image may be recorded by others during the class. Please speak with the instructor if this is a concern for you.

EXTREME CIRCUMSTANCES

The University reserves the right to change the dates and deadlines for any or all courses in extreme circumstances (e.g., severe weather, labour disruptions, etc.). Changes will be communicated through regular McMaster communication channels, such as McMaster Daily News, A2L and/or McMaster email.