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OFFICE OF THE SENATE COUNCIL

## 1. General Information

1a. Submitted by the College of: ENGINEERING

Date Submitted: 9/30/2015

1b. Department/Division: Electrical and Computer Engineering

1c. Contact Person

Name: Don Colliver

Email: dcolliver@uky.edu

Phone: 8-4348

Responsible Faculty ID (if different from Contact)

Name: Larry Holloway

Email: holloway@uky.edu

Phone: 323-8523

1d. Requested Effective Date: Semester following approval

1e. Should this course be a UK Core Course? No

## 2. Designation and Description of Proposed Course

2a. Will this course also be offered through Distance Learning?: No

2b. Prefix and Number: EE 543

2c. Full Title: Solar Cell Devices and Systems for Electrical Energy Generation

2d. Transcript Title: Solar Cell Devices &Systems

2e. Cross-listing: EGR 543, BAE 543

2f. Meeting Patterns

LECTURE: 3

2g. Grading System: Letter (A, B, C, etc.)

2h. Number of credit hours: 3

2i. Is this course repeatable for additional credit? No

If Yes: Maximum number of credit hours:

If Yes: Will this course allow multiple registrations during the same semester?

2j. Course Description for Bulletin: Physics of photovoltaic (PV) devices, emerging technologies, design of PV cells and systems, electronic components for signal conditioning, integration, installation, performance evaluation and economic issues related to PV systems.

2k. Prerequisites, if any: EE 211 or EE 305 and Engineering Standing, or consent of instructor

2l. Supplementary Teaching Component:

3. Will this course taught off campus? No

If YES, enter the off campus address:

4. Frequency of Course Offering: Spring,

Will the course be offered every year?: Yes

If No, explain:

5. Are facilities and personnel necessary for the proposed new course available?: Yes

If No, explain:

6. What enrollment (per section per semester) may reasonably be expected?: 18

7. Anticipated Student Demand

Will this course serve students primarily within the degree program?: Yes

Will it be of interest to a significant number of students outside the degree pgm?: Yes

If Yes, explain: Course will count towards Undergraduate or Graduate Certificate in Power and Energy

8. Check the category most applicable to this course: Not Yet Found in Many (or Any) Other Universities ,

If No, explain:

9. Course Relationship to Program(s).

a. Is this course part of a proposed new program?: No

If YES, name the proposed new program:

b. Will this course be a new requirement for ANY program?: No

If YES, list affected programs:

10. Information to be Placed on Syllabus.

a. Is the course 400G or 500?: Yes

b. The syllabus, including course description, student learning outcomes, and grading policies (and 400G-/500-level grading differentiation if applicable, from **10.a** above) are attached: Yes

## Distance Learning Form

Instructor Name:

Instructor Email:

Internet/Web-based: No

Interactive Video: No

Hybrid: No

1.How does this course provide for timely and appropriate interaction between students and faculty and among students? Does the course syllabus conform to University Senate Syllabus Guidelines, specifically the Distance Learning Considerations?

2.How do you ensure that the experience for a DL student is comparable to that of a classroom-based student's experience? Aspects to explore: textbooks, course goals, assessment of student learning outcomes, etc.

3.How is the integrity of student work ensured? Please speak to aspects such as password-protected course portals, proctors for exams at interactive video sites; academic offense policy; etc.

4.Will offering this course via DL result in at least 25% or at least 50% (based on total credit hours required for completion) of a degree program being offered via any form of DL, as defined above?

If yes, which percentage, and which program(s)?

5.How are students taking the course via DL assured of equivalent access to student services, similar to that of a student taking the class in a traditional classroom setting?

6.How do course requirements ensure that students make appropriate use of learning resources?

7.Please explain specifically how access is provided to laboratories, facilities, and equipment appropriate to the course or program.

8.How are students informed of procedures for resolving technical complaints? Does the syllabus list the entities available to offer technical help with the delivery and/or receipt of the course, such as the Information Technology Customer Service Center (http://www.uky.edu/UKIT/)?

9.Will the course be delivered via services available through the Distance Learning Program (DLP) and the Academic Technology Group (ATL)? NO

If no, explain how student enrolled in DL courses are able to use the technology employed, as well as how students will be provided with assistance in using said technology.

10.Does the syllabus contain all the required components? NO

11.I, the instructor of record, have read and understood all of the university-level statements regarding DL.

Instructor Name:

SIGNATURE|BJSTOK0|Barbara J Brandenburg|EE 543 NEW College Review|20160331

SIGNATURE|JMETT2|Joanie Ett-Mims|EE 543 NEW Undergrad Council Review|20160427

SIGNATURE|ZNNIKO0|Roshan N Nikou|EE 543 NEW Graduate Council Review|20160512

# New Course Form

https://myuk.uky.edu/sap/bc/soap/rfc?services=

Open in full window to print or save

Generate R

**Attachments:**

Browse... Upload File

| | ID | Attachment |
|---|---|---|
| Delete | 6456 | EE543.doc |

First 1 Last

(*denotes required fields)

**1. General Information**

a. * Submitted by the College of: ENGINEERING Submission Date: 9/30/2015

b. * Department/Division: Electrical and Computer Engineering

c.

* Contact Person Name: Don Colliver Email: dcolliver@uky.edu Phone: 8-4348

* Responsible Faculty ID (if different from Contact) Larry Holloway Email: holloway@uky.edu Phone: 323-8523

d. * Requested Effective Date: ◉ Semester following approval OR ○ Specific Term/Year [1]

e.

Should this course be a UK Core Course? ○ Yes ◉ No

**If YES, check the areas that apply:**

| | |
|---|---|
| ☐ Inquiry - Arts & Creativity | ☐ Composition & Communications - II |
| ☐ Inquiry - Humanities | ☐ Quantitative Foundations |
| ☐ Inquiry - Nat/Math/Phys Sci | ☐ Statistical Inferential Reasoning |
| ☐ Inquiry - Social Sciences | ☐ U.S. Citizenship, Community, Diversity |
| ☐ Composition & Communications - I | ☐ Global Dynamics |

**2. Designation and Description of Proposed Course.**

a. * Will this course also be offered through Distance Learning? ○ Yes [4] ◉ No

b. * Prefix and Number: EE 543

c. * Full Title: Solar Cell Devices and Systems for Electrical Energy Generation

d. Transcript Title (if full title is more than 40 characters): Solar Cell Devices & Systems

e. To be Cross-Listed [2] with (Prefix and Number): EGR 543, BAE 543

f. * Courses must be described by at least one of the meeting patterns below. Include number of actual contact hours[3] for each meeting pattern type.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 3 | Lecture | | Laboratory[1] | | Recitation | | Discussion |
| | Indep. Study | | Clinical | | Colloquium | | Practicum |
| | Research | | Residency | | Seminar | | Studio |
| | Other | If Other, Please explain: | | | | | |

g. * Identify a grading system:

◉ Letter (A, B, C, etc.)
○ Pass/Fail
○ Medicine Numeric Grade (Non-medical students will receive a letter grade)
○ Graduate School Grade Scale

h. * Number of credits: 3

i. * Is this course repeatable for additional credit? ○ Yes ◉ No

If YES: Maximum number of credit hours:

If YES: Will this course allow multiple registrations during the same semester? ○ Yes ○ No

j. * Course Description for Bulletin:

Physics of photovoltaic (PV) devices, emerging technologies, design of PV cells and systems, electronic components for signal conditioning, integration, installation, performance evaluation and economic issues related to PV systems.

k. Prerequisites, if any:

EE 211 or EE 305 and Engineering Standing, or consent of instructor

l. Supplementary teaching component, if any: ○ Community-Based Experience ○ Service Learning ◉ Both

3. * **Will this course be taught off campus?** ○ Yes ◉ No

If YES, enter the off campus address:

4. **Frequency of Course Offering.**

a. * Course will be offered (check all that apply): ☐ Fall ☑ Spring ☐ Summer ☐ Winter

b. * Will the course be offered every year? ◉ Yes ○ No

If No, explain:

5. * **Are facilities and personnel necessary for the proposed new course available?** ◉ Yes ○ No

If No, explain:

6. * **What enrollment (per section per semester) may reasonably be expected?** 18

7. **Anticipated Student Demand.**

a. * Will this course serve students primarily within the degree program? ◉ Yes ○ No

b. * Will it be of interest to a significant number of students outside the degree pgm? ◉ Yes ○ No

If YES, explain:

Course will count towards Undergraduate or Graduate Certificate in Power and Energy

8. * **Check the category most applicable to this course:**

☐ Traditional – Offered in Corresponding Departments at Universities Elsewhere
☐ Relatively New – Now Being Widely Established
☑ Not Yet Found in Many (or Any) Other Universities

9. **Course Relationship to Program(s).**

a. * Is this course part of a proposed new program? ○ Yes ◉ No

If YES, name the proposed new program:

b. * Will this course be a new requirement [5] for ANY program? ○ Yes ◉ No

If YES [5], list affected programs::

10. **Information to be Placed on Syllabus.**

a. * Is the course 400G or 500? ◉ Yes ○ No
If YES, the *differentiation for undergraduate and graduate students must be included* in the information required in **10.b**. You must include: (i) identi additional assignments by the graduate students; and/or (ii) establishment of different grading criteria in the course for graduate students. (See SR

b. ☑ * The syllabus, including course description, student learning outcomes, and grading policies (and 400G-/500-level grading differentiation if appl **10.a** above) are attached.

[3] Courses are typically made effective for the semester following approval. No course will be made effective until all approvals are received.
[4] The chair of the cross-listing department must sign off on the Signature Routing Log.

[3] In general, undergraduate courses are developed on the principle that one semester hour of credit represents one hour of classroom meeting per week for a semester, exclusive of any laboratory meeting. Laboratory meeting, generally, re two hours per week for a semester for one credit hour. (from SR 5.2.1)
[4] You must also submit the Distance Learning Form in order for the proposed course to be considered for DL delivery.
[5] In order to change a program, a program change form must also be submitted.

Rev 8/09

# SYLLABUS
# Proposed BAE/EE 543
# BAE599-003/EE599-002 (Spring 2016)
# Solar Cell Devices and Systems for Electrical Energy Generation

## Department of Electrical and Computer Engineering
## Department of Biosystems and Agricultural Engineering
## University of Kentucky
## Spring-2016

**Catalog Description:**
Physics of photovoltaic (PV) devices, emerging technologies, design of PV cells and systems, electronic components for signal conditioning, integration, installation, performance evaluation and economic issues related to PV systems.

**Prerequisites:**
Engineering Standing and EE 211 or EE 305, or consent of instructor

**Instructors:**
*Dr. Vijay Singh*, Professor of Electrical and Computer Engineering
E-Mail: vsingh@engr.uky.edu; Phone: (859) 257-3243; Office: 683 FPAT; Office Hours: MW, 3:00-5:00 p.m., or by appointment. The most effective way to contact me and/or make an appointment is via email. I check my e-mail several times during the day and also in the evening.

*Dr. Donald Colliver,* Professor of Biosystems and Agricultural Engineering, (859) 218-4348, Rm. 211 C.E. Barnhart Building, or Rm. 469 FPAT. Usually in office 9-5 and it's open for visitation or consultation at any time. Will usually be able to see you but due to erratic schedule an appointment is always helpful. The best way to reach me is via email. I regularly check my e-mail even while traveling, so you can always get me at dcolliver@uky.edu. Feel free to call at home before 8:00 pm. (Home phone number will be given in class.)

**Student Learning Outcomes:**
At the conclusion of this course, the student should be able to,

1. Explain the device physics underlying the operation of photovoltaic (PV) devices.
2. Design and model a photovoltaic cell.
3. Describe the operation of electronic components used in the maximization of PV system output.
4. Describe and analyze the integration, installation, performance evaluation and economic issues related to PV systems
5. Design and model a practical photovoltaic system.
6. Explain basic measurement techniques for device characterization and module performance evaluation of photovoltaic systems.

**Class Meeting Time:** Lectures: Tuesday and Thursday 12:30-1:45 (ET), FPAT 255

**Scheduled Final Exam:** Thursday, 5/5/16, 1:00pm
If you have three or more final exams scheduled on the same day and are requesting a rescheduling due to the limitation rule on final exam scheduling, a rescheduling request must be made in writing at least two weeks before the exam as per University rules.

**Textbook and Other Resources:**
Textbook 1(Required): Roger Messenger and Jerry Ventre, *Photovoltaic Systems Engineering, 3rd Ed.*, (CRC Press Taylor & Francis Group, 2010) ISBN 1439802920
Textbook 2 (Optional): Jenny Nelson, *The Physics of Solar Cells*, Imperial College Press, 2003, ISBN 1-86094-349-7
Online Resource: pveducation.org – pvcdrom
Online Resource: Material to be posted on Canvas throughout the semester
Handouts: Several handout documents to be distributed in class throughout the semester

**Software:**
PVWATTS, SAM – Downloadable from NREL
Listing of Modules http://www.photon.info/photon_site_db_solarmodule_en.photon
https://www.google.com/get/sunroof#p=0

**Grading:**
Two Exams (20% each); Final Exam (20%); Homework (10%); Quizzes (10%); Term Project (5% for mid report, 15% for final product; includes presentations).

Undergraduate: 90-100=A, 80-90=B, 70-80=C, 60-70=D, <60=E.
Graduate: 93-100=A, 83-92=B, 73-82=C, <72=E.
A curve may be applied at the end of the semester.

Some or all of the quizzes may be unannounced and no makeup quizzes will be given. The lowest quiz score will be dropped. While you may discuss with others the homework and approaches to solving it, in the end, each individual student must do the homework independently.

Mid-term grades will be posted in myUK by the deadline established in the Academic Calendar (http://www.uky.edu/registrar/content/academic-calendar)

**Differentiation for Undergraduate and Graduate Credit:**
In addition to different grading scales, grading differentiation for undergraduate and graduate students will also be made in the extent of the requirements for the Term Project. The graduate students will need to do an extensive economic analysis including price sensitivity, period of analysis, and tax policy implications; and analysis of multi-year performance diversity and production-load coincidence analysis.

**Exams:**
There will be three exams. The final exam will be cumulative. Failure to take an exam during the assigned class period will result in a grade of zero for that test. Other arrangements for taking an exam shall be made at least one week prior to the exam period in case of an excused absence.

**Electronic Devices:**
Cell phones shall be stowed during class, exams and quizzes (no use of calculator apps on cell phones). They may not be used for any reason, including texting, or as a calculator during exams/quizzes. Any questions on acceptability of devices shall be made no later than the class meeting prior to quiz or examination. If an emergency occurs and a cell phone needs to be used, please gather your things and leave the room for the rest of the session.

**Homework:**
Homework will be assigned almost every week. Problem solutions must show a clear systematic method for arriving at the correct solution for full credit. Points will be taken off for incorrect solutions or work that is difficult to follow.

The student is expected to read the textbook and is responsible for all material in the reading and Canvas assignments. Sections of the text covering the planned material should be read prior to the class meetings.

**Term Project:**
The term project will be to design either a battery charging system for electric vehicles or a residential solar PV system. These will include a three-line diagram of the wiring. The grading of the project will provide for 10% (of the points possible) for the individual who has the system with the shortest payback and others will be scaled accordingly based upon relative paybacks compared to the shortest submitted. The profit / overhead rates will be specified. Other costs such as interest rates, utility rates etc. will be obtained in homework / class presentations. A report will be due April 10th which describes progress to date. The final report shall also include an economic analysis. Output will need to show sensitivity to various parameters such as tilt, orientation, costs, etc.

**Inverted Classroom:**
Part of the class will be taught using a technique called the "inverted classroom". Students will be given an assignment of reviewing a web-based lecture before the class period. During the class period, students will be drawn at random to give a brief discussion of the material presented in the videoed lecture. The remainder of the class period will be used to go through example problems.

**Attendance:**
Attendance is expected, but is not directly tied to any portion of the course grade; however there will be no makeup for points not earned due to an unexcused absence or quiz that is missed due to an unexcused absence. The student is responsible for all business conducted during any scheduled class period. Any revision to the test dates, homework assignments, etc. will be announced during the class period. Absences due to participation in official university activities will only be excused if the instructor is notified at least one week in advance. Absences due to illness will be excused upon submittal the day of the class of an email indicating the medical absence. Verification may be required.

**Excused Absences**
*Senate Rules 5.2.4.2* defines the following as acceptable reasons for excused absences: (a) serious illness, (b) illness or death of family member, (c) University-related trips, (d) major religious holidays, and (e) other circumstances found to fit "reasonable cause for nonattendance" by the professor.

Students anticipating an absence for a major religious holiday are responsible for notifying the instructor in writing of anticipated absences due to their observance of such holidays no later than the last day in the semester to add a class. Two weeks prior to the absence is reasonable, but should not be given any later. Information regarding major religious holidays may be obtained through the Ombud (859-257-3737, http://www.uky.edu/Ombud/ForStudents_ExcusedAbsences.php.

Students are expected to withdraw from the class if more than 20% of the classes scheduled for the semester are missed (excused) per University policy.

Per *Senate Rule 5.2.4.2*, students missing any graded work due to an excused absence are responsible: for informing the Instructor of Record about their excused absence within one week following the period of the excused absence (except where prior notification is required); and for making up the missed work. The professor must give the student an opportunity to make up the work and/or the exams missed due to an excused absence, and shall do so, if feasible, during the semester in which the absence occurred.

**Verification of Absences**
Students may be asked to verify their absences in order for them to be considered excused. *Senate Rule 5.2.4.2* states that faculty have the right to request "appropriate verification" when students claim an excused absence because of illness, or death in the family. Appropriate notification of absences due to

University-related trips is required prior to the absence when feasible and in no case more than one week after the absence.

**Academic Integrity**
There is an expectation of academic honesty and of the absolute unacceptability of plagiarism and other forms of cheating.

Per University policy, students shall not plagiarize, cheat, or falsify or misuse academic records. Students are expected to adhere to University policy on cheating and plagiarism in all courses. The minimum penalty for a first offense is a zero on the assignment on which the offense occurred. If the offense is considered severe or the student has other academic offenses on their record, more serious penalties, up to suspension from the University may be imposed.

Plagiarism and cheating are serious breaches of academic conduct. Each student is advised to become familiar with the various forms of academic dishonesty as explained in the Code of Student Rights and Responsibilities. Complete information can be found at the following website: http://www.uky.edu/Ombud. A plea of ignorance is not acceptable as a defense against the charge of academic dishonesty. It is important that you review this information as all ideas borrowed from others need to be properly credited.

*Senate Rules 6.3.1* (see http://www.uky.edu/Faculty/Senate/ for the current set of *Senate Rules*) states that all academic work, written or otherwise, submitted by students to their instructors or other academic supervisors, is expected to be the result of their own thought, research, or self-expression. In cases where students feel unsure about a question of plagiarism involving their work, they are obliged to consult their instructors on the matter before submission.

When students submit work purporting to be their own, but which in any way borrows ideas, organization, wording, or content from another source without appropriate acknowledgment of the fact, the students are guilty of plagiarism.

Plagiarism includes reproducing someone else's work (including, but not limited to a published article, a book, a website, computer code, or a paper from a friend) without clear attribution. Plagiarism also includes the practice of employing or allowing another person to alter or revise the work, which a student submits as his/her own, whoever that other person may be. Students may discuss assignments among themselves or with an instructor or tutor, but when the actual work is done, it must be done by the student, and the student alone.

When a student's assignment involves research in outside sources or information, the student must carefully acknowledge exactly what, where and how he/she has employed them. If the words of someone else are used, the student must put quotation marks around the passage in question and add an appropriate indication of its origin. Making simple changes while leaving the organization, content, and phraseology intact is plagiaristic. However, nothing in these Rules shall apply to those ideas, which are so generally and freely circulated as to be a part of the public domain.

Please note: Any assignment you turn in may be submitted to an electronic database to check for plagiarism.

**Accommodations due to disability**
If you have a documented disability that requires academic accommodations, please see me as soon as possible during scheduled office hours. In order to receive accommodations in this course, you must provide me with a Letter of Accommodation from the Disability Resource Center (DRC). The DRC coordinates campus disability services available to students with disabilities. It is located on the corner of Rose Street and Huguelet Drive in the Multidisciplinary Science Building, Suite 407. You can reach

them via phone at (859) 257-2754 and via email at drc@uky.edu. Their web address is http://www.uky.edu/StudentAffairs/DisabilityResourceCenter/.

**First Homework Assignment:**
The assignment for the next meeting is a page that gives introductory information about you. This should include a picture, a description of your background (where you are from, education, major, etc), why you want to take this course and what you want to learn in it. It should be emailed to dcolliver@uky.edu. Your name and the course name/number must be included in the subject line.

## 2016 Tentative Lecture Schedule

PART ONE: Photovoltaic Systems: Integration, Installation, Performance Evaluation & Economic Issues (Colliver)
PART TWO: Photovoltaics: Device Physics, Technologies, Signal Conditioning and Manufacturing Issues (Singh)

| | Class # | Topic |
|---|---|---|
| Jan 14 | 1 | Class Introduction - Solar PV - Big Picture |
| 19 | 2 | Characteristics of Solar Radiation |
| 21 | 3 | Project Introduction |
| 26 | 4 | What Impacts the Amount of Radiation Available at the Surface<br>Calculation of Energy Received, Energy Production Estimation |
| 28 | 5 | Design of Grid Connected System |
| Feb 2 | 6 | Design of Grid Connected System |
| 4 | 7 | Design of Grid Connected System |
| 9 | 8 | Solar System Modeling |
| 11 | 9 | Solar System Modeling / Economics |
| 16 | 10 | Mechanical Design (Racking/anchoring) |
| 18 | 11 | Electrical Code Issues |
| 23 | 12 | Design of Grid Connected, Battery Backup |
| 25 | 13 | Design of Off Grid |
| Mar 1 | 14 | EXAM 1 |
| 3 | 15 | Electrons and Waves; Silicon Crystal<br>Holes; Effective Mass; Drift and Diffusion Currents |
| 8 | 16 | Electron-Hole Recombination; Continuity Equation |
| 10 | 17 | p-n Junction in Equilibrium; Junction Capacitance<br>(MIDTERM GRADES DUE 11th) |
| 15 | | Spring Break |
| 17 | | Spring Break |
| 22 | 18 | p-n Junction Diode in the Dark |
| 24 | 19 | p-n Junction Diode under Sunlight Illumination; Photocurrent,<br>Quantum Efficiency |
| 29 | 20 | Silicon Solar Cell; Energy Band Diagrams; Equivalent Circuit |
| 31 | 21 | Power Output; Maximum Power Point; Design Issues |
| April 5 | 22 | CdS-CdTe Thin Film Solar Cells |
| 7 | 23 | Cell Fabrication; From Cells to Modules; Automatic Series Connection<br>Multi-junction Solar Cells |
| 12 | 24 | Organic Semiconductor Solar Cells<br>Quantum Confinement; Nanotechnology and Photovoltaics |
| 14 | 25 | Buck and Boost Converters, Maximum Power Point Trackers (MPPT) |
| 19 | 26 | Batteries and Charge Controllers |
| 21 | 27 | EXAM 2 |
| 26 | 28 | Project Presentation |
| 28 | 29 | Project Presentation |
| May 5 | Final | |

Updated 12/15/15