ECE-8400-001/843 **Physics of Semiconductor Devices** **Spring - 2023**

Class Time: T, Th 11:00am - 12:15pm 223 Riggs Hall Wait-15 min.

Instructor: Dr. William R. Harrell Office: 205 Riggs Hall 656-5918
wharrel@clemson.edu

Office Hours: Tuesday & Thursday 3:30pm – 4:30pm
Other times by appointment: Office or Online via Zoom

Procedures: I plan to hold regular office hours in person, most of the time. However, when making appointments outside of regular office hours, the mode could be in my office in person OR via Zoom. It will depend on the day, my schedule, and yours. Just request a meeting via email.

TA: TBA Probably will not have a TA

Course Modality: Traditional / In-Person.

Textbook: J. P. Colinge, C. A. Colinge, *Physics of Semiconductor Devices*, Kluwer Academic Publishers, 2002. (Required)

Technology: The student is required to have a laptop computer, internet connectivity capable of transmitting and receiving video, a video camera, and a microphone. This is needed for Zoom office hours and other meetings.

Prerequisites: ECE-6040 Semiconductor Devices, or consent of instructor.

Class e-mail: I will set up a class e-mail list which I will use often to communicate with the class. You should check your e-mail daily, since I will send out important information and reminders this way! Note that any messages you send to the class list will go to every student in the class as well as to me. You can also easily contact me using my e-mail address listed above.

Attendance Policy: Attendance, in whatever mode is appropriate, is expected! You will learn more if you attend class regularly; however, you are responsible for all of the material covered in class whether you attend or not. The class lectures will sometimes carefully follow the text, sometimes go beyond the text, and sometimes follow just my notes instead of the presentation in the textbook. Thus, attendance is crucial!

Course Description: Semiconductor device physics emphasized; review of p-n junctions, analysis and models of Schottky diodes, MIS diodes, MOSFETs, traps, surface states and conduction processes; charge control concepts, transit time effects, BJTs. Students would benefit from having completed courses comparable to ECE 4040 and ECE 4060, but it is not required.

Goals/Outcomes: The goals of this course are to provide an in-depth knowledge of and understanding of the physics of semiconductor materials and some of the more technologically important semiconductor devices. Building on the background gained in ECE−6040 or related courses, and dependent upon student backgrounds, the general topics to be covered this semester are:

*Schottky Diodes & Thermionic Emission.
*JFETs and MESFETs.
*MOS and MIS Diodes/Capacitors, & CV Characterization and Modeling.
*Physics of the Si/SiO_2 and Semiconductor/Dielectric Interfaces.
*MOSFETs, n- and p-channel. Introduction to FINFETs.
*Bipolar Transistors and Heterojunction Devices

Properties of different modern semiconducting, conducting, and insulating materials, and their applications in electron devices, will be integrated throughout the course.

Theoretical physics, device modeling and simulation, device measurement issues, and practical engineering issues will be discussed in order to develop expertise in semiconductor physics and engineering.

Homework/Projects: Homework problems will be assigned periodically throughout the semester. These problems will include calculations, derivations, and extensions to the material covered in class. Some homework problems will come from the text, and some from me. The number of problems will be relatively small, but they will normally be challenging.

Projects will be assigned involving computer-aided analysis and simulation of semiconductor devices and materials. Some projects may require you to use simulation tools, some will require/recommend MATLAB, while others will require you to develop your own programs.

Assigned readings will primarily be from the textbook, but may also include books on reserve and/or journal papers.

Exams: There will be 2 regular written exams and a final exam. Show all of your work in neat, organized detail. The correct answer without showing how you arrived at it, won't receive full credit. The exams will consist of both problem solving/derivation questions and short essay questions, based on class notes and assigned readings.

Exam Attendance: If you cannot attend an exam for any reason, I should be notified ahead of time if possible, otherwise at least on the day of the exam. Except under unusual circumstances, no makeup will be given without appropriate notification. I will choose either a written or an oral makeup exam. If, for some reason, class is canceled on the day of a scheduled exam, the exam will be held on the next scheduled day of class.

Paper/Presentation: Each student will choose a device topic to research and study in depth. Formal oral presentations will be required, and a written paper will be required. We will hold the presentations near the end of the term, but we may hold some of them on campus and some of them online. The paper will be written according to the format requirements of *IEEE Transactions on Electron Devices*. This will give each student the experience of writing a paper of publication quality. The topics will be chosen subject to my approval, and they will be fairly narrow in scope. I will provide a list of suggested topics from which to choose, but you are not necessarily limited to that list. More detailed information on this assignment will be provided soon.

Conduct: All students are expected to act in a professional manner and to pay attention to the instructor during lectures. Behavior judged by the instructor to be distracting, discourteous, or disruptive will not be tolerated. Prohibited behavior includes, but is not limited to, excessive talking, sleeping, working on homework, reading, and improper use of electronic devices (including laptop computers, cell phones, and personal music players). Please do not start packing up your things before the end of class; the instructor will let you know when the class is dismissed. A student who fails to abide by these standards of conduct will be removed from the course and/or assigned a final grade of F.

Academic Integrity: As members of the Clemson University community, we have inherited Thomas Green Clemson's vision of this institution as a "high seminary of learning." Fundamental to this vision is a mutual commitment to truthfulness, honor, and responsibility, without which we cannot earn the trust and respect of others. Furthermore, we recognize that academic dishonesty detracts from the value of a Clemson degree. Therefore, we shall not tolerate lying, cheating, or stealing in any form. All infractions of academic dishonesty by undergraduates must be reported to Undergraduate Studies for resolution through that office. In cases of plagiarism instructors may use the Plagiarism Resolution Form. See the Undergraduate Academic Integrity Policy website for additional information and the current catalogue for the policy.

Accessibility: Clemson University values the diversity of our student body as a strength and a critical component of our dynamic community. Students with disabilities or temporary injuries/conditions may require accommodations due to barriers in the structure of facilities, course design, technology used for curricular purposes, or other campus resources. Students who experience a barrier to full access to this class should let the instructor know and make an appointment to meet with a staff member in Student Accessibility Services as soon as possible. You can make an appointment by calling 864-656-6848, by emailing studentaccess@lists.clemson.edu, or by visiting Suite 239 in the Academic Success Center building. Appointments are strongly encouraged - drop-ins will be seen if at all possible, but there could be a significant wait due to scheduled

appointments. Students who have accommodations are strongly encouraged to request, obtain, and send these to their instructors through their AIM portal as early in the semester as possible so that accommodations can be made in a timely manner. It is the student's responsibility to follow this process each semester. You can access further information at the Student Accessibility website. Other information is at the university's Accessibility Portal.

Title IX Statement: Clemson University is committed to a policy of equal opportunity for all persons and does not discriminate on the basis of race, color, religion, sex, sexual orientation, gender, pregnancy, national origin, age, disability, veteran's status, genetic information or protected activity in employment, educational programs and activities, admissions, and financial aid. This includes a prohibition against sexual harassment and sexual violence as mandated by Title IX of the Education Amendments of 1972. This Title IX policy is located on the Campus Life website. Ms. Alesia Smith is the Clemson University Title IX Coordinator, and the Executive Director of Equity Compliance. Her office is located at 223 Brackett Hall, 864.656.0620. Remember, email is not a fully secured method of communication and should not be used to discuss Title IX issues.

Safe Campus: Emergency procedures have been posted in all buildings and on all elevators. Students should be reminded to review these procedures for their own safety. All students and employees should be familiar with guidelines from the Clemson Police Department. Visit here for information about safety.

Clemson University is committed to providing a safe campus environment for students, faculty, staff, and visitors. As members of the community, we encourage you to take the following actions to be better prepared in case of an emergency:

1. Ensure you are signed up for emergency alerts
2. Download the Rave Guardian app to your phone (https://www.clemson.edu/cusafety/cupd/rave-guardian/)
3. Learn what you can do to prepare yourself in the event of an active threat (http://www.clemson.edu/cusafety/EmergencyManagement/)

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Extra Support: Clemson University provides many forms of academic support systems such as supplemental instruction (SI) and tutoring. Contact the Academic Success Center for more information. Clemson also provides other support services such as counseling and psychological services. For a list of links to various services provided go to the following URL: https://www.clemson.edu/asc/

Grading: Final grades will be determined by averaging the homework/projects, paper/presentation, regular exams, and the final exam based on the following scale:

Homework/Projects	20%	
Paper/Presentation	15%	(10% / 5%)
2 Exams	40%	(20% each)
Final Exam	25%	
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Course Grade	100%	

Grading Scale:		
	90 - 100	A
	80 - 89	B
	70 - 79	C
	0 - 69	F

*I reserve the right to adjust the grading scale depending on overall class performance, but only in your favor.

Note-1: *The Canvas Grade Book is for your information and convenience. Official grades are kept in my office/laptop, and these are the true grades. It is the student's responsibility to verify the accuracy of their Canvas grades.*

Note-2: *The instructor reserves the right to modify any aspect of this syllabus at any time during the semester for reasons including, but not limited to, COVID-related situations.*

Version #1 Date: 1/11/2023

Topical Coverage

This class will be topical, which means that we will study several topics in device physics in depth, using various sources. My notes will be based on the textbook, other literature, and my own experience. The schedule will be somewhat loose, in that we will spend as much time as necessary in order to cover a topic. My basic plan for topical coverage is listed below, but actual coverage may vary. Coverage may also vary somewhat depending upon students' background.

Topic	**Text Coverage**	**Number of Class Lectures**
Introduction & Background	N/A	6
Schottky Diodes & Thermionic Emission	Chapter 5	2
JFETs and MESFETs	Chapter 6	2
MOS/MIS Devices	Chapter 7 + Notes	12
Bipolar Transistors	Chapter 8	3
Heterojunction Devices	Chapter 9	2

NOTES: Total of 29 Class Periods this Semester.
Total of 27 classes used in Topical Coverage.
Two classes will be used for Exams 1 & 2.

Final Exam: **Wednesday, May 3** **3:00pm - 5:30pm**
Final Exam will be Somewhat Comprehensive

Note: *Actual schedule may vary slightly depending on class progress.*

Changes to Syllabus: The instructor reserves the right to make changes to this syllabus during the semester. Students will be given adequate notice in class of any changes.

Version #2 Date: 1/11/2023