COLUMBIA | ENGINEERING
The Fu Foundation School of Engineering and Applied Science

ELEN E3106: Solid State Devices and Materials
Electrical Engineering
Fall 2025

COURSE DESCRIPTION

Semiconductor devices are the underlying technology in every solid state active electronic circuit. This course will introduce the fundamental concepts of semiconductor physics and use them to construct fundamental device models for PN diodes, BJTs, and MOSFETs. We will begin with crystal structure and energy band theory of solids. Carrier concentration and drift/diffusion transport will be examined. Along the way, we will see how the same device fundamentals can be used to explain a number of other charge carrier drift/diffusion-based devices including junctions, photodetectors, solar cells, and light emitting devices. Fabrication techniques and device process variation will be covered. This course will build a student's knowledge of semiconductor fundamentals.

COURSE SCHEDULE

Time: Tuesday, Thursday 11:40am - 12:55pm
Location: International Affairs Building (IAB) 417

INSTRUCTOR

Prof. Savannah Eisner
Mudd Building, Office 1328
savannah.eisner@columbia.edu

TEACHING ASSISTANT (TA)

Ethan Liu
yl5188@columbia.edu

COURSE ASSISTANTS (CAs)

Akanksha Sahoo
as7466@columbia.edu

Sunny Hu
yh3553@columbia.edu

OFFICE HOURS (Tentative – check back after first week of class)

Prof. Eisner: TBD
Ethan (TA): TBD

RECITATION (Tentative – check back after first week of class)

Ethan (TA): 11:45am on Fridays (location TBD)

CREDITS

3.5 credits

TEXTBOOKS

Required: B. G. Streetman, S. K. Banerjee, *Solid State Electronic Devices*, 7th ed., Pearson/Prentice Hall, 2014. ISBN-10: 0133356035. ISBN-13: 978-0133356038.

Required (free online): C. C. Hu, *Modern Semiconductor Devices for Integrated Circuits*, 3rd ed., Wiley, 2007. (https://www.chu.berkeley.edu/modern-semiconductor-devices-for-integrated-circuits-chenming-calvin-hu-2010/)

GRADING POLICY

- 30% Homework
- 20% Exam 1
- 20% Exam 2
- 30% Final Exam

Homework

A total of 9 problem sets will be assigned as homework. Homework will be due Fridays by 5pm ET via submission on Courseworks.

Exams

Two exams will be administered during regularly scheduled class time. The exams will be closed book and notes will not be allowed. A formula and constants sheet will be provided. Calculator required. You will receive an automatic zero if the TA or instructor sees your phone during the exam.

Final Exam

The final exam will be administered at the time and location specified by the registrar (tentative time: Thursday December 18th 4:10-7pm). The final will be closed book and notes will not be allowed. A formula and constants sheet will be provided. Calculator required.

Please refer to the School Handbook for further details on grading and good academic standing.

COURSE COMMUNICATION

Courseworks

This will be the main hub for this class. It will serve as a repository for all course files including homework assignments and solutions, grades, lecture slides, annotated lecture slides, and lecture recordings. Homework assignments will also be submitted here.

Ed Discussion

We will be using Ed Discussion, which is integrated into Courseworks, as an online discussion and communication tool. Rather than emailing questions on the homework or technical concepts to the teaching staff , we encourage you to post your questions on Ed Discussion. Questions reach and benefit all students in the class. The staff will do our best to answer questions promptly.

POLICIES AND EXPECTATIONS

Homework Policy

Your homework set with the lowest grade, including no submission, will be dropped (e.g. it will not count towards your grade). Late homework will be accepted within 48 hours with the following penalty: -20% for 0-24 hours late, and -40% for 24-48 hours late. Example: Homework is due Friday at 5pm. Homework sets submitted by 5pm Saturday will receive a maximum grade of 80%, while homework sets submitted by 5pm Sunday will receive a maximum grade of 60%. Under no circumstances will other extensions be granted unless the instructor receives official notice from the Center for Student Advising that you will require academic accommodations. Technical issues are not an accepted excuse for late work. In the event you experience a technical issue that prevents you from uploading to Courseworks, it is expected that you will email the homework to the TA and the instructor by the deadline INCLUDING a screenshot of the ticket you submit to CUIT for help with the technical issue precluding submission on Courseworks.

Academic Integrity

Students are required to adhere to Columbia University guidelines on academic integrity. For more information on student policies, please visit the Academic Integrity website (https://www.cc-seas.columbia.edu/integrity) and the Center for Student Success and Intervention website (https://cssi.columbia.edu/content/learn-about-policies). A list of general Columbia Engineering Academic Policies can be found on the website (https://www.engineering.columbia.edu/academics/policies).

Collaboration

Students are allowed to work together on the homework sets. Each student must submit the assignment in their own personalized document or handwriting, with the solution for each problem fully worked out, to receive credit. If you have any questions regarding this policy, please ask the instructor or TA.

Exam Conflicts and Accommodations

If you require an accommodation for a documented disability (see policy below) or a change in schedule due to a religious observance, contact the instructor at least a week in advance. Other than these two scenarios, make-up exams will not be given unless the instructor receives official notice

from the Center for Student Advising that you will require academic accommodations. If an exam is missed without prior approval from the instructor it will receive zero credit.

Disability Access

In order to receive disability-related academic accommodations, students must first be registered with the Office of Disability Services (ODS). Students who have or think they may have a disability are invited to contact ODS for a confidential discussion at 212.854.2388 (V) 212.854.2378 (TTY), or by email at disability@columbia.edu. If you have already registered with ODS, please speak to your instructor to ensure that they have been notified of your recommended accommodations at least one week before any exam.

COURSE LEARNING OBJECTIVES

By the time you complete this course, you will master:

- Charge transport and carrier statistic equations relevant to crystalline semiconductors
- Energy band diagrams and their applications
- Characteristics of PN junctions and PN diode devices
- BJT characteristics, including internal, small signal macroscopic, and large signal macroscopic models
- MOS capacitor characteristics
- MOSFET characteristics, including internal, small signal macroscopic, and large signal macroscopic models
- Applications of these principles to basic optical energy conversion devices, including solar cells and LEDs

ADDITIONAL RESOURCES

Free Online Resources

- B. Van Zeghbroeck, *Principles of Semiconductor Devices,* a free online textbook. (https://www.eletrica.ufpr.br/graduacao/e-books/Principles%20Of%20Semiconductor%20Devices.pdf)
- ECE 440 on nanoHUB (https://nanohub.org/resources/5221)
- Britney Spears' guide to semiconductor physics (http://britneyspears.ac/lasers.htm)

More Resources

- D. K. Bhattacharya, R. Sharma, *Solid State Electronic Devices*, 2nd edition, Oxford Univeristy Press, 2013. (available for free through Columbia libraries/Knovel. Click next to green checkmark here: https://clio.columbia.edu/catalog/12110723?counter=1)
- R. F. Pierret, *Semiconductor Device Fundamentals*, Addison-Wesley, 1996.
- S. M. Sze and K.K. Ng, *Physics of Semiconductor Devices*, 3rd ed., Wiley, 2007.

COURSE SCHEDULE

Please note: course schedule is subject to change as the semester progresses based on our pace.

Week	Date	Lecture	Topic	Reading and assignments
1st	Sept 2nd (Tues)	1	Introduction to the course and semiconductor devices	Read syllabus
	Sept 4th (Thurs)	2	Semiconductors & Crystal Properties	Streeman & Bannerjee §1.1, 1.2. Review Ch. 2
2nd	Sept 9th (Tues)	3	Bonding Forces & Energy Bands in Solids	Streeman & Bannerjee §3.1
	Sept 11th (Thurs)	4	Charge Carriers in Semiconductors & Intro to Fermi Levels	Streeman & Bannerjee §3.2, 3.3.1 **HW 1 due Fri Sept 12th by 5pm**
3rd	Sept 16th (Tues)	5	Carriers: Temperature dependency, **drift**, mobility, and resistance	Streeman & Bannerjee §3.3.2-3.3.4, 3.4
	Sept 18th (Thurs)	6	Diffusion of Carriers	Streeman & Bannerjee §4.4.1-4.4.4 **HW 2 due Fri Sept 19th by 5pm**
4th	Sept 23rd (Tues)	7	Optical absorption, luminescence, carrier lifetime and photoconductivity (end of coverage for Exam 1)	Streeman & Bannerjee §4.1-4.3
	Sept 25th (Thurs)	8	p-n Junctions Part I	Streeman & Bannerjee §5.2 **HW 3 due Fri Sept 26th by 5pm**
5th	Sept 30th (Tues)	**Exam 1 (Chapters 1, 3, and 4)**		
	Oct 2nd (Thurs)	9	p-n Junctions Part II	Streeman & Bannerjee §5.2
6th	Oct 7th (Tues)	10	Metal-Semiconductor Junctions and Contacts	Streeman & Bannerjee §5.7; C. Hu Ch. 4 Part III
	Oct 9th (Thurs)	11	Device Fabrication	Streeman & Bannerjee §5.1 **HW 4 due Fri Oct 10th by 5pm**
7th	Oct 14th (Tues)	12	Optoelectronics Part I: Solar Cells & Photodiodes	Streeman & Bannerjee §8.1
	Oct 16th (Thurs)	13	Optoelectronics Part II: LEDs and Lasers	Streeman & Bannerjee §8.2-8.4

				HW 5 due Fri Oct 17th by 5pm
8th	Oct 21st (Tues)	14	p-n Junction Breakdown and Narrow Base Diodes (end of coverage for Exam 2)	Streeman & Bannerjee §5.4
	Oct 23rd (Thurs)	15	BJTs Part I	Streeman & Bannerjee §7.1-7.2 **HW 6 due Fri Oct 24th by 5pm**
9th	Oct 28th (Tues)	**Exam 2 (Chapters 5 and 8)**		
	Oct 30th (Thurs)	16	BJTs Part II	C. Hu §8.1-8.4
10th	Nov 4th (Tues)	University Holiday; no class (Election Day)		
	Nov 6th (Thurs)	17	BJTs Part III: Modes of Operation and Secondary Effects	C. Hu §8.4, 8.6-8.7
11th	Nov 11th (Tues)	18	BJTs Part IV: Models and Secondary Effects	C. Hu §8.6-8.10
	Nov 13th (Thurs)	19	MOS Capacitor Part I	C. Hu §5.1-5.5 **HW 7 due Fri Nov 14th by 5pm**
12th	Nov 18th (Tues)	20	MOS Capacitor Part II	C. Hu §5.6, 5.10.1
	Nov 20th (Thurs)	21	MOSFETs Part I	**HW 8 due Fri Nov 21st by 5pm**
13th	Nov 25th (Tues)	22	MOSFETs Part II	
	Nov 27th (Thurs)	University Holiday; no class (Thanksgiving)		
14th	Dec 2nd (Tues)	23	MOSFETs Part III	
	Dec 4th (Thurs)	24	Review Session (Extra Credit Opportunity)	**HW 9 due Fri Dec 5th by 5pm**
	Dec 18th (Thurs)	**Final Exam, 4:10 – 7pm (Location TBD)**		