

## **ECE 371 – MATERIALS AND DEVICES**

**Instructor:** Prof. Daniel Feezell  
**Office Location:** ECE Main Office (Room 125)  
**Office Hours:** After class or by appointment  
**Class Meeting Day(s):** Tuesday/Thursday  
**Class Location / Room:** Northrop Hall | Room 122

**Email:** dfeezell@unm.edu  
**Office Phone:** 272-7823  
**Course Credits:** 3  
**Class Time:** 11:00 am – 12:15 pm  
**Term / Semester:** Fall 2025

### **Teaching Assistant:**

Abdelrahman Elshafiey  
Electrical & Computer Engineering Department  
E-mail: atarief@unm.edu  
Office Hours: Monday 12-1:30 pm, Wednesday 12-1:30 pm  
Office Hours Location: Tables on 2<sup>nd</sup> floor of ECE building

### **Class Website:**

<https://canvas.unm.edu/>

I will post the syllabus, homework assignments and solutions, lecture slides, project information, exam solutions, and other course materials. The website requires you to login using your UNM NetID. A detailed course schedule is also available on the course website. This schedule includes the material to be covered, recommended sections of the book for reading, exam dates, and homework assignments and due dates. Please note that the schedule is approximate.

### **Course Goal:**

- Introduce students to the fundamentals of semiconductors materials to gain a better understanding of the operation of modern transistors (and other semiconductor devices).

### **Student Learning Outcomes:**

At the end of the course, you should be able to:

- Understand the fundamentals of crystal structures
- Understand the basic quantum mechanics associated with semiconductors and how to solve the Schrodinger equation for simple potential functions
- Understand energy band diagrams, effective mass, density of states, and the Fermi-Dirac distribution
- Understand intrinsic and extrinsic semiconductors
- Understand basic transport mechanisms in semiconductors
- Understand pn junctions in equilibrium and under forward and reverse bias
- Understand MOS capacitors and the fundamental operation of MOSFETs
- Apply the learned concepts, principles, rules, and theories to understand more complex electronic and optoelectronic devices
- Explain what you learned during the course

### **Topics Covered:**

Semiconductor materials (Ch. 1) - crystal structures, unit cells, miller indices, bonding, imperfections, and growth. Quantum mechanics (Ch. 2) – the uncertainty principle, Schrodinger equation, wave functions, electrons in free space, infinite potential wells, step potential functions, and tunneling. Quantum theory of solids (Ch. 3) – energy bands, Kronig-Penney model,

dispersion curves, effective mass, holes, density of states, and Fermi-Dirac distribution. Semiconductors in equilibrium (Ch. 4) – equilibrium carrier concentrations, Fermi-level position, dopant atoms, III-V semiconductors, extrinsic semiconductors, and charge neutrality. Carrier transport (Ch. 5) – drift current, mobility, conductivity, diffusion current, and Einstein relation. PN junctions (Ch. 7) – built-in potential, electric field, space charge width, reverse bias, and breakdown. PN junction diodes (Ch. 8) – charge flow, current-voltage relation, minority carrier distribution, and ideal diode equation. MOSFETs (Ch. 10) – MOSFET structures, energy band diagrams, surface charge density, flat band voltage, threshold voltage, basic MOSFET operation.

**Required Text:**

“Semiconductor Physics and Devices: Basic Principles,” D. A. Neamen, McGraw Hill, 4<sup>th</sup> edition (2012), ISBN: 978-0-07-352958-5.

**Reference Text:**

“Solid State Electronic Devices,” B.G. Streetman and S. Banerjee, Prentice Hall, 5th edition (2000), ISBN: 0-13-025538-6

**Prerequisites:**

Physics 2310 or 262 and ECE 300 (or equivalent differential equations and linear algebra)

**Assessment/Grading:**

|                                                                                 |     |
|---------------------------------------------------------------------------------|-----|
| Homework (8 homework assignments, see details below)                            | 20% |
| Midterm Exam 1 (Thursday 9/18, 11:00am-12:15pm, covers ch. 1-2)                 | 20% |
| Midterm Exam 2 (Tuesday 11/4, 11:00am-12:15pm, covers ch. 3-5)                  | 20% |
| PN Diode Design Project Using NanoHUB (due 12/4)                                | 10% |
| Final Exam (Tuesday 12/9, 12:30pm-2:30pm, cumulative but focused on ch. 7,8,10) | 30% |

**Undergraduate Student Grading Scale:**

| <b><u>Letter grade</u></b> | <b><u>Percentage Points</u></b> |
|----------------------------|---------------------------------|
| <u>A+</u> :                | <u>96-100</u>                   |
| <u>A</u> :                 | <u>92-95.9</u>                  |
| <u>A-</u> :                | <u>88-91.9</u>                  |
| <u>B+</u> :                | <u>84-87.9</u>                  |
| <u>B</u> :                 | <u>80-83.9</u>                  |
| <u>B-</u> :                | <u>76-79.9</u>                  |
| <u>C+</u> :                | <u>72-75.9</u>                  |
| <u>C</u> :                 | <u>68-71.9</u>                  |
| <u>C-</u> :                | <u>64-67.9</u>                  |
| <u>D+</u> :                | <u>60-63.9</u>                  |
| <u>D</u> :                 | <u>56-59.9</u>                  |
| <u>D-</u> :                | <u>52-55.9</u>                  |
| <u>F</u> :                 | <u>Below 52</u>                 |

Note: all grades in the ECE undergraduate program must be C or better to be considered passing.

### **Graduate Student Grading Scale:**

| <b><u>Letter grade</u></b> | <b><u>Percentage Points</u></b> |
|----------------------------|---------------------------------|
| <u>A+:</u>                 | <u>98-100</u>                   |
| <u>A:</u>                  | <u>94-97.9</u>                  |
| <u>A-:</u>                 | <u>90-93.9</u>                  |
| <u>B+:</u>                 | <u>86-89.9</u>                  |
| <u>B:</u>                  | <u>82-85.9</u>                  |
| <u>B-:</u>                 | <u>78-81.9</u>                  |
| <u>C+:</u>                 | <u>74-77.9</u>                  |
| <u>C:</u>                  | <u>70-73.9</u>                  |
| <u>F:</u>                  | <u>Below 70</u>                 |

Note: Graduate students may be asked to complete additional homework problems of a more advanced nature compared to the homework problems given to undergraduate students.

### **Homework:**

There will be eight (8) homework assignments throughout the semester. Due to the size of the class, two problems per assignment will be randomly selected and graded to determine your homework score. Late homework assignments will not be accepted as I will post the solutions to the assignments right after you turn in your homework. Homework is due ***before the beginning of the class period on the due date. Please submit homework to Canvas.*** Homework should be neatly written, with each problem labeled. Show your work in a logical fashion to get maximum credit and ***please box your final answers!*** If the problem says “plot” you should use Excel, Matlab, or some other numerical tool, if the problem says draw or sketch, you can do it by hand. **I will drop the lowest homework score from the grade calculation!**

### **PN Diode Design Project:**

The project will consist of designing a PN diode to achieve operation satisfying a pre-determined set of specifications. We will use a free software tool from nanoHUB (<https://nanohub.org/tools/pntoy>). More information on the project will be given later in the semester.

### **Midterm Exams:**

There will be two midterm exams. The first exam will cover chapters 1 and 2, while the second exam will cover chapters 3, 4, and 5. The midterm exams are closed book, but you will be allowed ***one*** 8.5” x 11” page (front and back) of notes for each exam.

### **Final Exam:**

The final will be cumulative but focus on chapters 7, 8, and 10. The final exam is closed book, but you will be allowed ***two*** 8.5” x 11” pages (front and back) of notes.

**Approximate Course Schedule (Example for Fall 2025):**

| Date   | Day      | Event      | Book (Chapter) | Material Covered                                                                      | Reading     |
|--------|----------|------------|----------------|---------------------------------------------------------------------------------------|-------------|
| 19-Aug | Tuesday  | Lecture 1  | Ch 1           | syllabus overview, intro, semiconductor materials, types of solids, unit cells        | 1.1-1.3     |
|        |          |            |                |                                                                                       |             |
|        |          |            |                |                                                                                       |             |
| 21-Aug | Thursday | Lecture 2  | Ch 1           | miller indices, directions, planes, bonding, diamond structure, imperfections, growth | 1.4-1.7     |
|        |          |            |                |                                                                                       |             |
|        |          |            |                |                                                                                       |             |
| 26-Aug | Tuesday  | Lecture 3  | Ch 2           | energy quanta, wave particle duality, uncertainty principle, Schrodinger equation     | 2.1-2.2.1   |
|        |          |            |                |                                                                                       |             |
|        |          |            |                |                                                                                       |             |
| 28-Aug | Thursday | Lecture 4  | Ch 2           | physical meaning of the wave function, boundary conditions, electrons in free space   | 2.2.2-2.3.1 |
|        |          |            |                |                                                                                       |             |
|        |          |            |                |                                                                                       |             |
| 2-Sep  | Tuesday  | No class   | No class       | No class                                                                              |             |
|        |          |            |                |                                                                                       |             |
|        |          |            |                |                                                                                       |             |
| 4-Sep  | Thursday | Lecture 5  | Ch 2           | infinite potential well, step potential function                                      | 2.3.2-2.3.3 |
|        |          |            |                |                                                                                       |             |
|        |          |            |                |                                                                                       |             |
| 9-Sep  | Tuesday  | Lecture 6  | Ch 2           | step potential function, potential barrier, tunneling                                 | 2.3.3-2.3.4 |
|        |          |            |                |                                                                                       |             |
|        |          |            |                |                                                                                       |             |
| 11-Sep | Thursday | Lecture 7  | Ch 3           | formation of energy bands, Kronig-Penney model                                        | 3.1         |
|        |          |            |                |                                                                                       |             |
|        |          |            |                |                                                                                       |             |
| 16-Sep | Tuesday  | Lecture 8  | Ch 3           | Kronig-Penny model, k-space model, E vs. k, energy bands                              | 3.1         |
|        |          |            |                |                                                                                       |             |
|        |          |            |                |                                                                                       |             |
| 18-Sep | Thursday | Midterm 1  |                | Covers Ch 1 and Ch 2                                                                  |             |
|        |          |            |                |                                                                                       |             |
|        |          |            |                |                                                                                       |             |
| 23-Sep | Tuesday  | Lecture 9  | Ch 3           | band model, drift current, effective mass, holes                                      | 3.2         |
|        |          |            |                |                                                                                       |             |
|        |          |            |                |                                                                                       |             |
| 25-Sep | Thursday | Lecture 10 | Ch 3           | effective mass, density of states (DOS)                                               | 3.3, 3.4    |
|        |          |            |                |                                                                                       |             |
|        |          |            |                |                                                                                       |             |
| 30-Sep | Tuesday  | Lecture 11 | Ch 4           | Fermi-Dirac distribution,                                                             | 3.5,        |

|        |          |            |           |                                                                                     |             |
|--------|----------|------------|-----------|-------------------------------------------------------------------------------------|-------------|
|        |          |            |           | equilibrium distribution of electrons and holes                                     | 4.1.1-4.1.2 |
| 2-Oct  | Thursday | Lecture 12 | Ch 4      | $n_0$ and $p_0$ , intrinsic carrier concentration, intrinsic Fermi-level position   | 4.1.3-4.3.1 |
|        |          |            |           |                                                                                     |             |
| 7-Oct  | Tuesday  | Lecture 13 | Ch 4      | dopant atoms and energy levels, III-Vs, extrinsic semiconductors, $n_0 p_0$ product | 4.3.1-4.4.2 |
|        |          |            |           |                                                                                     |             |
| 9-Oct  | Thursday | Fall Break |           | No class                                                                            | 4.5, 4.6    |
|        |          |            |           |                                                                                     |             |
|        |          |            |           |                                                                                     |             |
| 14-Oct | Tuesday  | Lecture 14 | Ch 4      | statistics of donors and acceptors, charge neutrality                               | 4.5, 4.6    |
|        |          |            |           |                                                                                     |             |
|        |          |            |           |                                                                                     |             |
| 16-Oct | Thursday | Lecture 15 | Ch 5      | Fermi level position, drift current density, mobility                               | 5.1.1-5.1.2 |
|        |          |            |           |                                                                                     |             |
|        |          |            |           |                                                                                     |             |
| 21-Oct | Tuesday  | Lecture 16 | Ch 5      | mobility, conductivity, velocity saturation                                         | 5.1.2-5.1.4 |
|        |          |            |           |                                                                                     |             |
|        |          |            |           |                                                                                     |             |
| 23-Oct | Thursday | Lecture 17 | Ch 5      | diffusion current, total current, induced electric fields, Einstein relation        | 5.2-5.3     |
|        |          |            |           |                                                                                     |             |
|        |          |            |           |                                                                                     |             |
| 28-Oct | Tuesday  | Lecture 18 | Ch 7      | basic PN junction structure, built-in potential                                     | 7.1-7.2.1   |
|        |          |            |           |                                                                                     |             |
|        |          |            |           |                                                                                     |             |
| 30-Oct | Thursday | Lecture 19 | Ch 7      | built-in potential and electric field                                               | 7.2.1-7.2.2 |
|        |          |            |           |                                                                                     |             |
|        |          |            |           |                                                                                     |             |
| 4-Nov  | Tuesday  | Midterm 2  | Midterm 2 | Covers Ch 3, Ch 4, and Ch 5                                                         |             |
|        |          |            |           |                                                                                     |             |
|        |          |            |           |                                                                                     |             |
| 6-Nov  | Thursday | Lecture 20 | Ch 7      | space charge width                                                                  | 7.2.3       |
|        |          |            |           |                                                                                     |             |
|        |          |            |           |                                                                                     |             |
| 11-Nov | Tuesday  | Lecture 21 | Ch 7      | reverse bias, junction capacitance, one sided junctions                             | 7.3.1-7.3.3 |
|        |          |            |           |                                                                                     |             |
|        |          |            |           |                                                                                     |             |
| 13-Nov | Thursday | Lecture 22 | Ch 8      | intro to pn junction diode, forward bias, charge flow, minority carriers            | 8.1.1-8.1.4 |
|        |          |            |           |                                                                                     |             |
|        |          |            |           |                                                                                     |             |
| 18-Nov | Tuesday  | Lecture 23 | Ch 8      | junction boundary conditions, minority carrier distribution, ideal                  | 8.1.5-8.1.6 |
|        |          |            |           |                                                                                     |             |

|        |          |               |       |                                                                                                        |               |
|--------|----------|---------------|-------|--------------------------------------------------------------------------------------------------------|---------------|
|        |          |               |       | diode equation                                                                                         |               |
| 20-Nov | Thursday | Lecture 24    | Ch 10 | MOS intro, energy band diagrams, depletion layer thickness, surface charge density                     | 10.1.1-10.1.5 |
|        |          |               |       |                                                                                                        |               |
| 25-Nov | Tuesday  | Lecture 25    | Ch 10 | work function differences, flat band voltage, threshold voltage, MOS capacitor, FET modes of operation | 10.2          |
|        |          |               |       |                                                                                                        |               |
| 27-Nov | Thursday | Thanksgiving  | Ch 10 | Thanksgiving                                                                                           | 10.3.1-10.3.2 |
|        |          |               |       |                                                                                                        |               |
| 2-Dec  | Tuesday  | Lecture 26    | Ch 10 | Basic MOSFET Operation                                                                                 | 10.3.1-10.3.2 |
|        |          |               |       |                                                                                                        |               |
| 4-Dec  | Thursday | Lecture 27    |       | Make up class or review                                                                                |               |
|        |          |               |       |                                                                                                        |               |
| 9-Dec  | Tuesday  | Final         | Final | Comprehensive but focused on Ch 7, Ch 8, and Ch 10.                                                    |               |
|        |          | 12:30-2:30 pm |       |                                                                                                        |               |
|        |          |               |       |                                                                                                        |               |

**Credit-hour statement:** This is a three-credit-hour course. Class meets for two 75-minute sessions of direct instruction for fifteen weeks during the Fall 2025 semester. Please plan for a minimum of six hours of out-of-class work (homework, studying, assignment completion, and/or class preparation) each week.

**Attendance Policy:** Regular and punctual attendance is required. UNM Pathfinder policies apply, which in part means instructor drops based on non-attendance are possible. This policy applies regardless of the grading option you have chosen.

**Accommodations:** UNM is committed to providing equitable access to learning opportunities for students with documented disabilities. As your instructor, it is my objective to facilitate an inclusive classroom setting, in which students have full access and opportunity to participate. To engage in a confidential conversation about the process for requesting reasonable accommodations for this class and/or program, please contact Accessibility Resource Center (<https://arc.unm.edu/>) at [arcsrvs@unm.edu](mailto:arcsrvs@unm.edu) or by phone at 505-277-3506.

**Title IX:** The University of New Mexico and its faculty are committed to supporting our students and providing an environment that is free of bias, discrimination, and harassment. The University's programs and activities, including the classroom, should always provide a space of mutual respect, kindness, and support without fear of harassment, violence, or discrimination. Discrimination on the basis of sex includes discrimination on the basis of assigned sex at birth, sex characteristics, pregnancy and pregnancy related conditions, sexual orientation and gender identity. If you have encountered any form of discrimination on the basis of sex, including sexual harassment, sexual assault, stalking, domestic or dating violence, we encourage you to report this

to the University. You can access the confidential resources available on campus at the LoboRESPECT Advocacy Center (<https://loborespect.unm.edu>), the Women's Resource Center (<https://women.unm.edu>), and the LGBTQ Resource Center (<https://lgbtqrc.unm.edu>). If you speak with an instructor (including a TA or a GA) regarding an incident connected to discrimination on the basis of sex, they must notify UNM's Title IX Coordinator that you shared an experience relating to Title IX, even if you ask the instructor not to disclose it. The Title IX Coordinator is available to assist you in understanding your options and in connecting you with all possible resources on and off campus. For more information on the campus policy regarding sexual misconduct and reporting, please see <https://policy.unm.edu/university-policies/2000/2740.html> and CEEO's [website](#).

If you are pregnant or experiencing a pregnancy-related condition, you may contact UNM's Office of Compliance, Ethics, and Equal Opportunity at [ceeo@unm.edu](mailto:ceeo@unm.edu). The CEEO staff will provide you with access to available resources and supportive measures and assist you in understanding your rights.

**Student Support:** Confidential services for students are available at [LoboRESPECT Advocacy Center](#), [Women's Resource Center](#), and the [LGBTQ Resource Center](#). The [Women's Resource Center](#) supports all students, including those who are pregnant or are parents. UNM's lactation stations are marked on the [UNM campus map](#).

Student Support: Resources to support study skills and time management are available through [Student Learning Assistance](#) at the Center for Teaching and Learning in Zimmerman Library or online.

**Responsible Learning and Academic Honesty:** Cheating and plagiarism (academic dishonesty) are often driven by lack of time, desperation, or lack of knowledge about how to identify a source. Communicate with me and ask for help, even at the last minute, rather than risking your academic career by committing academic dishonesty. Academic dishonesty involves presenting material as your own that has been generated on a website, in a publication, by an artificial intelligence algorithm (AI), by another person, or by otherwise breaking the rules of an assignment or exam. It is a [Student Code of Conduct](#) violation that can lead to a disciplinary procedure. When you use a resource (such as an AI, article, a friend's work, or a website) in work submitted for this class, document how you used it and distinguish between your original work and the material taken from the resource.

**Cell Phones and Technology:** As a matter of courtesy, please turn off cell phones, pagers, and other communication and entertainment devices prior to the beginning of class. Notify me in advance if you are monitoring an emergency, for which cell phone ringers should be switched to vibrate. *Cell phones and smart watches will not be permitted during exams.*

**Library and Tutorial Services:** UNM-Main campus provides many library services and some tutorial services for distance students. For library services, go to <http://www.unm.edu/libraries/> to link to a specific library or to contact a librarian. For tutorial services, go to <http://caps.unm.edu/online> to explore UNM's online services.

**Communication on Change in Modality:** The President and Provost of UNM may direct that classes move to remote delivery at any time to preserve the health and safety of the students,

instructor and community. The instructor will provide any updates about our class and please check <https://bringbackthepack.unm.edu> regularly for general UNM updates about COVID-19 and the health of our community.

**Weather Policy:** In the event of severe weather conditions UNM may close. Please call 277-SNOW to check UNM's status during questionable weather conditions.

**Copyright Policy and Law:** *(University Counsel's Office - Subject to Change Without Notice)*

The unauthorized distribution of copyrighted material, including through peer-to-peer file sharing, may subject a student to criminal and civil penalties. The laws that govern copyright are not specific to any one technology. Students can violate the rights of a copyright holder using many different types of technology. Both uploading and downloading of files can pose a violation of the copyright law. Students should be cautious when obtaining any copyrighted material. As a rule of thumb, before a student receives anything for free, they should research whether that source provides material licensed by the copyright owner. A group called EDUCAUSE has a list of legal file sharing alternatives at <http://www.educause.edu/legalcontent>.

Individuals who violate copyright law by illegally uploading and downloading copyrighted files may be subject to civil penalties of between \$750 and \$150,000 per song. These penalties are established by federal law. In the past, pre-litigation settlements offered by copyright owners have been in the \$3,000 to \$4,000 and up range while juries in some jurisdictions have issued verdicts of hundreds of thousands and up. In addition, a court may, in its discretion, grant the copyright owner reasonable attorney fees. Although criminal prosecution of students for file sharing is extremely rare, federal law lays out criminal penalties for intentional copyright infringement which can include fines and jail time. In addition to potentially violating the law, unauthorized distribution or receipt of copyrighted material is a violation of University Business Policies and Procedures Manual 2500. That policy states that: "Users shall respect all copyrights including software copyrights...Use of University computing services in violation of applicable laws or University policy may result in sanctions, including withdrawal of use privilege; disciplinary action, up to and including, expulsion from the University or discharge from a position; and legal prosecution under applicable federal and/or state law."

**Land Acknowledgment:**

The University of New Mexico (founded in 1889) sits on the traditional homelands of the Pueblo of Sandia. The original peoples of New Mexico Pueblo, Navajo, and Apache since time immemorial, have deep connections to the land and have made significant contributions to the broader community statewide. We honor the land itself and those who remain stewards of this land throughout the generations and also acknowledge our committed relationship to Indigenous peoples. We gratefully recognize our history.