



**ECE 7831 MICROWAVE SEMICONDUCTOR DEVICES,  
ELECTRICAL AND COMPUTER ENGINEERING  
AUTUMN 2020 – ONLINE, SYNCHRONOUS**

## COURSE OVERVIEW

### Instructor

Patrick Roblin ([roblin.1@osu.edu](mailto:roblin.1@osu.edu)) (he/his)

Office hours: by appointment (using CarmenZoom)

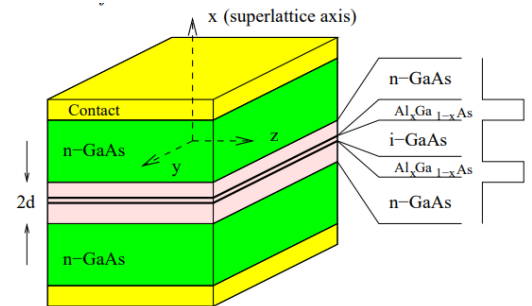
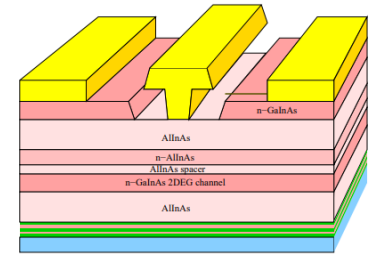
### Course description

Principles of microwave semiconductor devices; scattering and high-field transport; Gunn effect; FET wave equation, HEMT; HBT; large signal RF modeling and measurements; noise; traps; self-heating. Preq: 3030 or equivalent. Recommended: 5030.

### Course learning outcomes

Upon successful completion of this course, each student will be able to:

1. Provide a detailed understanding of the operation of classical and quantum heterostructure devices and their high-frequency (radio frequency) response
2. Review semi-classical theories of heterostructure devices and their application to the PN heterojunction and the HBT
3. Discuss resonant tunneling diodes and superlattices and their high frequency response
4. Provide an understanding of the scattering processes contributing to transport in heterostructures including processes such as scattering-assisted resonant tunneling
5. Discuss high field transport, velocity overshoot, velocity saturation and the Gunn effect and the consequences on the operation of Gunn diodes, HEMTs and HBTs
6. Discuss the physical operation of HEMTs and HBTs including two-dimensional effects and short-channel effects, and the development of high-frequency small- and large-signal electro-thermal models
7. Measurement and modeling techniques of small and large signal RF response and noise processes in microwave devices and the characterization of memory effects such as traps, self-heating and cyclostationary effects



<u>ABET related student learning outcomes</u>	Course contribution		
	Some	Substantial	Significant
1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.			X
2. An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, <b>safety</b> , and welfare, as well as global, cultural, social, <b>environmental</b> , and <b>economic</b> factors	X		
3. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies		X	

<u>NACE related Student learning outcomes</u>	Course contribution		
	Some	Substantial	Significant
• Critical thinking/problem solving			X
• Oral/written communications		X	
• Teamwork/collaboration			
• Digital technology		X	
• Leadership			
• Professionalism/work-ethic			
• Career management			
• Global/intercultural fluency			

## HOW THIS COURSE WORKS

**Mode of delivery:** This course is 100% online using CarmenCanvas and CarmenZoom. There are three weekly lecture sessions (synchronous in-person / real time video with recorded lectures available). Each lecture will start with a review of the materials covered in the previous lecture followed by a series of Top Hat quizzes before proceeding to the new lecture.

**Pace of online activities:** This course is divided into **weekly modules** that are released at the beginning of the semester excluding recorded lectures. Some elements may be updated during the course. Students are expected to keep pace with weekly deadlines.

**Credit hours and work expectations:** This is a **3-credit-hour course**. According to [Ohio State policy](#), students should expect around 3 hours per week of time spent on direct instruction (instructor content and Carmen activities, for example) in addition to 6 hours of outside work (readings, homework, and project assignments, for example) to receive a passing grade.

**Attendance and participation requirements:** Consistent engagement is expected. All lectures will be delivered synchronously but will be recorded; you will be expected to log into CarmenZoom at the appropriate time to participate synchronously. If any problems arise relative to attendance, please contact the instructor as soon as possible. Communication is important. You are encouraged to participate “in class”, ask questions, work on in-class problems in small groups, and share your experiences relative to the subjects and discussion that day.

The online lectures will be interactive. Active in-class participation is found to greatly correlate with students’ performance, thus synchronously participation is requested. The lecture slides and video will be posted on CarmenCanvas, so if you do miss a lecture, you are expected to view the missed material before the next lecture. The following is a summary of everyone's expected participation:

- **Participating in live sessions and/or online activities: THREE TIMES PER WEEK**  
You are expected to log in to the course in Carmen, CarmenZoom every week. If you have any hardship situation (working in a different time zone, become sick, or had difficulty find a quiet space) let me know so that we work out a solution. This will involve with make-up assignments to replace the in-class quizzes. If you have a situation that might cause you to miss an entire week of class, discuss it with me as soon as possible.
- **Office hours: AT LEAST ONCE PER SEMESTER.** General office hours are optional but encouraged.
- **Required course materials and technologies:** CarmenCanvas, CarmenZoom.

## REQUIRED

- *High-Speed Heterostructure Devices*, P. Roblin and H. Rohdin, *Cambridge University Press*, 2002.

## RECOMMENDED/OPTIONAL

- *Nonlinear Transistor Model Parameter Extraction Techniques*. M. Rudolph, C. Fager, and D. Root, Cambridge University Press, 2012

## Course technology

For help with your password, university email, Carmen, or any other technology issues, questions, or requests, contact the Ohio State IT Service Desk. Standard support hours are available at [ocio.osu.edu/help/hours](https://ocio.osu.edu/help/hours), and support for urgent issues is available 24/7.

- **Self-Service and Chat support:** [ocio.osu.edu/help](https://ocio.osu.edu/help)
- **Phone:** 614-688-4357(HELP)
- **Email:** [servicedesk@osu.edu](mailto:servicedesk@osu.edu)
- **TDD:** 614-688-8743

## BASELINE TECHNICAL SKILLS FOR ONLINE COURSES

- Basic computer and web-browsing skills
- Navigating Carmen: for questions about specific functionality, see the [Canvas Student Guide](#).
- Familiarity with Matlab

## REQUIRED TECHNOLOGY SKILLS SPECIFIC TO THIS COURSE

- [CarmenZoom virtual meetings](#)
- [Recording a slide presentation with audio narration \(with captioning\)](#)

## REQUIRED EQUIPMENT

- Computer: current Mac (OS X) or PC (Windows 7+) with high-speed internet connection
- Webcam: built-in or external webcam, fully installed and tested
- Microphone: built-in laptop or tablet mic or external microphone
- Other: a mobile device (smartphone or tablet) or landline to use for BuckeyePass authentication

## REQUIRED SOFTWARE

- [Microsoft Office 365](#): All Ohio State students are now eligible for free Microsoft Office 365 ProPlus through Microsoft's Student Advantage program. Full instructions for downloading and installation can be found [at go.osu.edu/office365help](https://go.osu.edu/office365help).

- Matlab and PISCES will be available on the ECE linux workstations via FastX
- Top Hat: available at: <https://www.ohio.edu/oit/services/teaching/top-hat>

## CARMEN ACCESS

You will need to use [BuckeyePass](#) multi-factor authentication to access your courses in Carmen. To ensure that you are able to connect to Carmen at all times, it is recommended that you take the following steps:

- Register multiple devices in case something happens to your primary device. Visit the [BuckeyePass - Adding a Device](#) help article for step-by-step instructions.
- Request passcodes to keep as a backup authentication option. When you see the Duo login screen on your computer, click **Enter a Passcode** and then click the **Text me new codes** button that appears. This will text you ten passcodes good for 365 days that can each be used once.
- Download the [Duo Mobile application](#) to all of your registered devices for the ability to generate one-time codes in the event that you lose cell, data, or Wi-Fi service.

If none of these options will meet the needs of your situation, you can contact the IT Service Desk at 614-688-4357 (HELP) and IT support staff will work out a solution with you.

## GRADING AND FACULTY RESPONSE

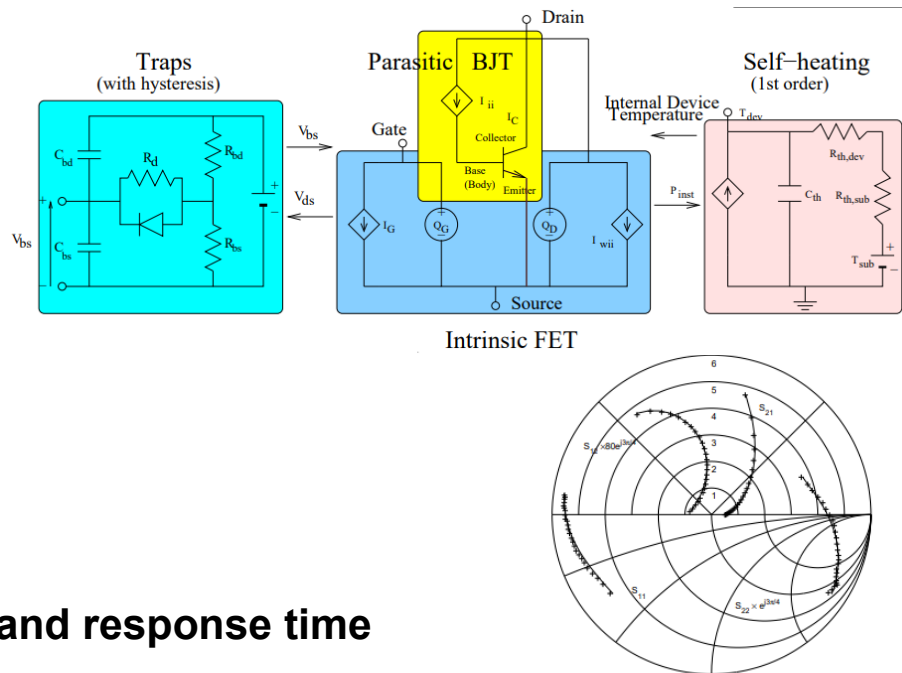
### How your grade will be calculated

ASSIGNMENT CATEGORY	POINTS
In class Top-Hat quizzes	10
Homework (8)	30
Midterm exam (Take home)	30
Final exam: Design Project & Presentations	30
<b>Total</b>	<b>100</b>

*See course schedule on CarmenConnect for all detailed assignments and due dates.*

## Grading scale

- 93–100: A  
 90–92.9: A-  
 87–89.9: B+  
 83–86.9: B  
 80–82.9: B-  
 77–79.9: C+  
 73–76.9: C  
 70–72.9: C-  
 67–69.9: D+  
 60–66.9: D  
 Below 60: E



## Instructor feedback and response time

- **Grading and feedback:** For large weekly assignments, you can generally expect feedback within **7 days**.
- **Email:** I will try to reply to emails within **24 hours on days when class is in session at the university**. If somehow, I do not, please resend your email.

## Course Evaluation

- A series of evaluation tools will be used throughout the course. Final evaluation will include University SEI and forms developed by the instructor. During final exam week, you will schedule an online interview with the course instructor to evaluate your mastery of semiconductor device physics, receive direct feedback on your CAD project, debrief on the course, and provide suggestions for improvement.

## OTHER COURSE POLICIES

### Discussion and communication guidelines

The following are expectations for how we should communicate as a class. Above all, please remember to be respectful of and thoughtful.

- **Writing style:** While there is no need to participate in class discussions as if you were writing a research paper, you should remember to write using good grammar, spelling, and punctuation. A more conversational tone is fine for non-academic topics.
- **Tone and civility:** Let's maintain a supportive learning community where everyone feels safe and where people can disagree amicably. Remember that sarcasm doesn't always come across online.
- **Citing your sources:** When we have academic discussions, please cite your sources to back up what you say. For the textbook, journal articles, or other course materials, list at least the author, title, and page numbers. For online sources, include a link.
- **Backing up your work:** Consider composing your academic posts in a word processor, where you can save your work, and then copying into the Carmen discussion.

## Academic integrity policy

### OHIO STATE'S ACADEMIC INTEGRITY POLICY

Academic integrity is essential to maintaining an environment that fosters excellence in teaching, research, and other educational and scholarly activities. Thus, The Ohio State University and the Committee on Academic Misconduct (COAM) expect that all students have read and understand the university's [Code of Student Conduct](#), and that all students will complete all academic and scholarly assignments with fairness and honesty. Students must recognize that failure to follow the rules and guidelines established in the university's *Code of Student Conduct* and this syllabus may constitute "Academic Misconduct."

The Ohio State University's *Code of Student Conduct* (Section 3335-23-04) defines academic misconduct as: "Any activity that tends to compromise the academic integrity of the university or subvert the educational process." Examples of academic misconduct include (but are not limited to) plagiarism, collusion (unauthorized collaboration), copying the work of another student, and possession of unauthorized materials during an examination. Ignorance of the university's *Code of Student Conduct* is never considered an excuse for academic misconduct, so I recommend that you review the *Code of Student Conduct* and, specifically, the sections dealing with academic misconduct.

**If I suspect that a student has committed academic misconduct in this course, I am obligated by university rules to report my suspicions to the Committee on Academic Misconduct.** If COAM determines that you have violated the university's *Code of Student Conduct* (i.e., committed academic misconduct), the sanctions for the misconduct could include a failing grade in this course and suspension or dismissal from the university.

If you have any questions about the above policy or what constitutes academic misconduct in this course, please contact me.

Other sources of information on academic misconduct (integrity) to which you can refer include:

- The Committee on Academic Misconduct web pages ([COAM Home](#))
- *Ten Suggestions for Preserving Academic Integrity* ([Ten Suggestions](#))
- *Eight Cardinal Rules of Academic Integrity* ([www.northwestern.edu/uacc/8cards.htm](http://www.northwestern.edu/uacc/8cards.htm))

## POLICIES FOR THIS ONLINE COURSE

**Class Only Exam Policy:** Midterms and final exam will all be take-home exam. Exams will be open book/notes. Students will not communicate with anybody else during the exam.

**Class Homework Policy:** Homework will be graded based on effort so as not to penalize students who are working alone.

## Copyright disclaimer

The materials used in connection with this course may be subject to copyright protection and are only for the use of students officially enrolled in the course for the educational purposes associated with the course. Copyright law must be considered before copying, retaining, or disseminating materials outside of the course.

## Statement on Title IX

All students and employees at Ohio State have the right to work and learn in an environment free from harassment and discrimination based on sex or gender, and the university can arrange interim measures, provide support resources, and explain investigation options, including referral to confidential resources.

If you or someone you know has been harassed or discriminated against based on your sex or gender, including sexual harassment, sexual assault, relationship violence, stalking, or sexual exploitation, you may find information about your rights and options at [titleix.osu.edu](http://titleix.osu.edu) or by contacting the Ohio State Title IX Coordinator at [titleix@osu.edu](mailto:titleix@osu.edu). Title IX is part of the Office of Institutional Equity (OIE) at Ohio State, which responds to all bias-motivated incidents of harassment and discrimination, such as race, religion, national origin and disability. For more information on OIE, visit [equity.osu.edu](http://equity.osu.edu) or email [equity@osu.edu](mailto:equity@osu.edu). Note that OSU instructors are mandated reporters.



## Your mental health

As a student you may experience a range of issues that can cause barriers to learning, such as strained relationships, increased anxiety, alcohol/drug problems, feeling down, difficulty concentrating and/or lack of motivation. These mental health concerns or stressful events may lead to diminished academic performance or reduce a student's ability to participate in daily activities. The Ohio State University offers services to assist you with addressing these and other concerns you may be experiencing. If you find yourself feeling isolated, anxious or overwhelmed, please know that there are resources to help: [ccs.osu.edu](https://ccs.osu.edu). You can reach an on-call counselor when CCS is closed at (614) 292-5766 and 24 hour emergency help is also available through the 24/7 National Prevention Hotline at 1-(800)-273-TALK or at [suicidepreventionlifeline.org](https://suicidepreventionlifeline.org). The Ohio State Wellness app is also a great resource available at [go.osu.edu/wellnessapp](https://go.osu.edu/wellnessapp).

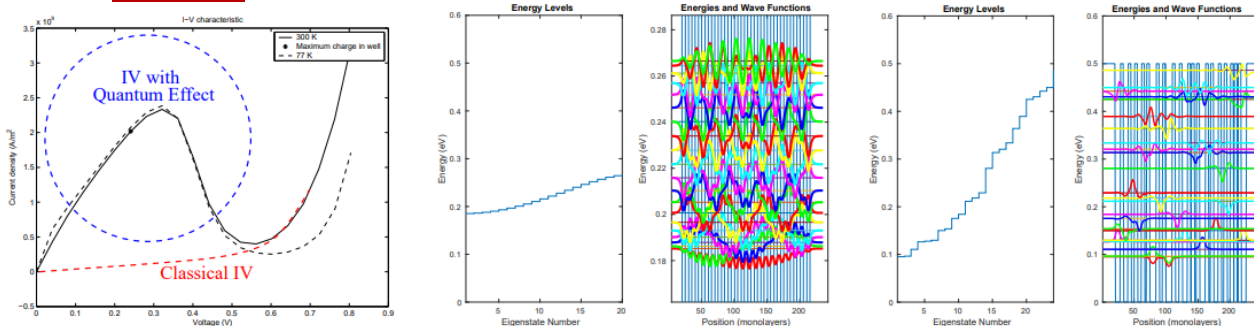
## Student Emergency Financial Support

The **Student Advocacy Center** staff members are continuing to serve students during normal business hours and are accepting online appointments.

The **Student Emergency Fund** is available to students who may otherwise be at risk of dropping out of college due to an unexpected financial emergency. If you, or a student you know, are experiencing an unplanned expense, the Student Emergency Fund may be an option. Their office is accepting applications and may be able to award up to \$1,000 to eligible students. [Learn more and apply.](#)

The Together As Buckeyes emergency grants program, funded primarily by the federal Coronavirus Aid, Relief and Economic Security (CARES) Act, is available to all students — undergraduate, graduate and professional — through the Student Financial Aid office. To apply for a grant, students need to complete a one-page [Emergency Request form](#) and provide any supporting documentation. The Office of Student Financial Aid will process applications after determining eligibility based on each student's circumstances and guidance from the U.S. Department of Education.

Franklin County Department of Job and Family Services has amended its Prevention, Retention and Contingency Program to provide targeted relief for families impacted by the COVID-19 pandemic. The Franklin County COVID-19 Response PRC Program provides eligible families with \$500 in one-time cash assistance to help address emergent needs and expenses brought about by the public health emergency. Families can [apply online](#) today. The **Student Wellness Center** offers financial coaching through the Scarlet and Gray Financial nationally recognized peer financial coaching program. Through the program, students will learn about financial goal setting, banking basics, budgeting, credit education, debt repayment education and saving and retirement education. [Learn more.](#)



## Food Assistance

It's a common idea that pervades American culture: when you're in college, it's simply a rite of passage to sustain yourself on cheap, unhealthy food. We disagree. We highly recommend OSU's **Buckeye Food Alliance** Lincoln Tower 150 food pantry (<https://www.buckeyefoodalliance.org>) and the MidOhio Foodbank (<https://www.midohiofoodbank.org>). The **Buckeye Food Alliance** will remain open to support students in need. Starting Monday, March 23 the pantry will be open Monday/Thursday 10 a.m. – 2 p.m.; Tuesday/Wednesday 4 – 8 p.m. and Friday 11 a.m. – 3 p.m. If these times do not work for your schedule, you can schedule a special appointment by contacting Nick Fowler at [fowler.318@osu.edu](mailto:fowler.318@osu.edu).

## ACCESSIBILITY ACCOMMODATIONS FOR STUDENTS WITH DISABILITIES

### Requesting accommodations

The university strives to make all learning experiences as accessible as possible. If you anticipate or experience academic barriers based on your disability including mental health, chronic or temporary medical conditions, please let me know immediately so that we can privately discuss options. To establish reasonable accommodations, I may request that you register with Student Life Disability Services. After registration, make arrangements with me as soon as possible to discuss your accommodations so that they may be implemented in a timely fashion. **SLDS contact information:** [slds@osu.edu](mailto:slds@osu.edu); 614-292-3307; 098 Baker Hall, 113 W. 12<sup>th</sup> Avenue.

### Accessibility of course technology

This online course requires use of Carmen (Ohio State's learning management system) and other online communication and multimedia tools. If you need additional services to use these technologies, please request accommodations with your instructor.

- [CarmenCanvas accessibility](#)
- Streaming audio and video
- [CarmenZoom accessibility](#)
- Collaborative course tools

## COURSE TOPICS

These topics will be discussed throughout the course:

- 1 Introduction to Heterostructure Devices. Semi-Classical Theory, HBT.
- 2 Quantum Theory of Heterostructures and Quantum Heterostructure Devices (Quantum well, RTD, superlattice)
- 3 Scattering Processes and Scattering-Assisted Tunneling in Heterostructures Devices and High-Frequency Response of Quantum Devices (RTD, Infrared laser)
- 4 Charge Control of the Two-Dimensional Electron Gas in HEMT
- 5 High Electric-Field Transport in Semiconductor Devices
- 6 Current Voltage Models of the Short-Channel MOSFET, HEMT, SOI and LDMOS
- 7 MOSFET Wave-Equation. Microwave Modeling and Electrothermal effects.
- 8 Noise modeling. On wafer microwave measurement.
- 9 High-Frequency Heterojunction Bipolar Transistors
- 10 Non-linear RF measurement and modeling. Impact of thermal and electrical memory effect on the large-signal RF response.

Additional Special Topics for 2020 Offering:

- GaN HEMTs: physics, modeling and high-power microwave applications
- Non-linear RF characterization with a Large Signal Network Analyzer (NVNA)
- Impact of self-heating & trapping on transistor characteristics
- Pulsed-IV pulsed-RF measurements as a probe of device physics
- Joint LSNA / DLOS measurements of GaN HEMTs
- On-wafer RF measurements, deembedding, Cold FET parasitics extraction
- $1/f$  noise and cyclostationary effects under large-signal RF operation
- Development of a nonlinear embedding device models for accelerated PA design

# COURSE SCHEDULE

<b>Week</b>	<b>Topics</b>	<b>Readings (all assignments &amp; deadlines provided on Carmen Canvas)</b>
<b>1</b>	Introduction to heterostructure devices Heterostructure materials Semiclassical theory of heterostructures	<b>Chapters 1 &amp; 2</b>
<b>2</b>	Quantum theory of heterostructures Quantum heterostructure devices	<b>Chapters 3 &amp; 4</b>
<b>3</b>	Scattering processes in heterostructures Scattering assisted tunneling	<b>Chapters 5 &amp; 6</b>
<b>4</b>	Frequency response of quantum devices Charge control in 2DEG	<b>Chapters 7 &amp; 8</b>
<b>5</b>	High electric field transport I-V model of HEMTs	<b>Chapters 9 &amp; 10</b>
<b>6</b>	Small-signal and large signal AC models for the long and short channel MODFET	<b>Chapters 11 &amp; 12</b>
<b>7</b>	Electro-thermal characterization Trap effects in GaN HEMTs	<b>Chapter 13 &amp; references</b>
<b>8</b>	Nonlinear embedding device models for accelerated PA design	<b>References</b>
<b>9</b>	Non-linear RF characterization with a Large Signal Network Analyzer	<b>References &amp; DML talk</b>
<b>10</b>	Impact of nonlinearity and memory effects in PA communication applications	<b>References &amp; DML talk</b>
<b>11</b>	Layout and distributed effects in manifold	<b>References</b>
<b>12</b>	Noise modeling. On wafer microwave measurement	<b>Chapters 15, 16 &amp; 17</b>
<b>13</b>	High-Frequency Heterojunction Bipolar Transistors	<b>Chapters 18 &amp; 19</b>
<b>14</b>	<b>Break, recitation</b>	
<b>15</b>	<b>In class project presentations</b>	
<b>16</b>	<b>In class project presentations</b>	
<b>Finals Week</b>	<b>Final exam</b>	