

Identification	Subject	ETR 211 Semiconductor Devices, 6 ECTS credits
	Department	Physics and Electronics
	Program (Undergraduate, Graduate)	Undergraduate
	Term	Fall 2026
	Instructor	Ph.D. Shirkhan Humbatov
	Email:	shirkhan.humbatov@khazar.org shirxanhumbatov@gmail.com
	Classroom/hours	AZ1096 Baku, Mahsati Street 11, Azerbaijan (Nefitchilar Campus), Thursday-Saturday, 08:30–15:35
Prerequisites	None	
Language	English	
Compulsory/Elective	Elective	
Textbooks and course materials	Required textbook: [1] Neamen, D. A. Semiconductor Physics and Devices: Basic Principles, 4th ed., McGraw-Hill, 2012. Recommended textbooks: [2] Streetman, B. G., & Banerjee, S. K. Solid State Electronic Devices, 7th ed., Pearson. [3] Pierret, R. F. Semiconductor Device Fundamentals, Pearson, 1996. Course materials: [4] Instructor lecture notes, handouts, worked examples, laboratory guidance, and assigned problem sets. Supplementary learning resources: MIT OpenCourseWare 6.012 – Microelectronic Devices and Circuits; MIT 6.720J – Integrated Microelectronic Devices; Stanford EE116 – Semiconductor Devices for Energy and Electronics. Note: All page numbers in the tentative schedule refer to the printed page numbers of Neamen, 4th ed.	
Course description	Semiconductor Devices provides a rigorous, physics-based study of semiconductor materials and the operation of modern electronic and optoelectronic devices. The course begins with semiconductor materials, energy-band theory, electrons and holes, intrinsic and extrinsic semiconductors, doping, carrier statistics, and Fermi-level concepts. Charge transport is developed through drift, diffusion, mobility, conductivity, the Einstein relation, and Hall-effect measurements. A dedicated treatment of nonequilibrium excess carriers introduces generation–recombination, continuity equations, ambipolar transport, quasi-Fermi levels, carrier lifetime, Shockley–Read–Hall recombination, and surface effects. The course then examines p–n junction electrostatics and diode transport, metal–semiconductor contacts and heterojunctions, MOS capacitors and MOSFETs, MOSFET scaling and nonideal effects, bipolar transistors, JFETs, MESFETs, and HEMTs. Specialized devices include solar cells, photodetectors, LEDs, laser diodes, microwave devices, power BJTs, power MOSFETs, and thyristors. Introductory semiconductor fabrication, device noise, and selected emerging technologies are incorporated through the textbook prologue and instructor materials. Throughout the course, students connect physical models, energy-band diagrams, device equations, and I–V/C–V characteristics with practical	

	semiconductor technologies.
Course objectives	The main objective of this course is to establish a rigorous conceptual and quantitative foundation in semiconductor physics and device operation. The course aims to: • Develop a clear understanding of semiconductor materials, energy-band formation, electrons and holes, intrinsic and extrinsic behavior, doping, carrier concentrations, and Fermi-level statistics. • Develop proficiency in analyzing carrier transport through drift, diffusion, mobility, conductivity, the Einstein relation, and Hall-effect principles. • Establish a quantitative understanding of nonequilibrium excess carriers, including generation–recombination, continuity equations, quasi-Fermi levels, carrier lifetime, Shockley–Read–Hall recombination, and surface effects. • Develop a physics-based understanding of p–n junction electrostatics and diode current–voltage behavior, including depletion width, junction capacitance, recombination currents, transient response, and breakdown. • Enable students to analyze Schottky and ohmic contacts, semiconductor heterojunctions, MOS capacitors, MOSFETs, BJTs, JFETs, MESFETs, and HEMTs using energy-band and carrier-transport concepts. • Introduce advanced MOSFET behavior, scaling, short-channel and high-field effects, and the physical limitations that govern modern transistor performance. • Connect semiconductor physics with optical, microwave, and power devices, including solar cells, photodetectors, LEDs, laser diodes, Gunn and IMPATT devices, power transistors, and thyristors. • Relate device physics to semiconductor fabrication, noise, reliability, wide-bandgap materials, and selected emerging semiconductor technologies.
Learning Outcomes	By the end of the course, students will be able to: • Explain and quantitatively analyze semiconductor energy bands, intrinsic and extrinsic materials, doping, carrier concentrations, and Fermi-level position. • Calculate drift and diffusion current densities and interpret mobility, conductivity, the Einstein relation, and Hall-effect measurements. • Analyze nonequilibrium carrier behavior using generation–recombination rates, continuity equations, quasi-Fermi levels, minority-carrier lifetime, and Shockley–Read–Hall concepts. • Analyze p–n junction electrostatics and diode characteristics, including built-in potential, depletion width, junction capacitance, ideal and nonideal I–V behavior, breakdown, and switching transients. • Interpret Schottky contacts, ohmic contacts, and semiconductor heterojunctions using energy-band diagrams and carrier-transport mechanisms. • Evaluate MOS-capacitor and MOSFET behavior through accumulation, depletion, inversion, C–V characteristics, threshold voltage, I–V relations, transconductance, and substrate-bias effects. • Assess MOSFET nonidealities and scaling limitations, including channel-length modulation, velocity saturation, ballistic transport, short-channel effects, breakdown, and hot-electron effects. • Analyze BJT, JFET, MESFET, and HEMT operation in terms of carrier injection, transport, gain, pinch-off, transconductance, frequency response, and switching behavior. • Explain the operating principles of major optoelectronic, microwave, and

	power semiconductor devices and relate performance to material and device parameters. • Relate semiconductor fabrication, device noise, and selected emerging technologies to device structure, performance, reliability, and practical applications.		
Teaching methods	Lecture		✓
	Seminar / problem solving		✓
	Assisted work		x
	Assisted laboratory work		✓
Evaluation Criteria	Methods	Date/deadlines	Percentage (%)
	Midterm Exam	TBC	30
	Quizzes	TBA, Four quizzes during the semester	20
	Practical Assignments	-	0
	Activity	During the semester	10
	Attendance	At each lesson	5
	Final Exam	TBC	35
	Total		100
Class Policy	Preparation for class Semiconductor Devices requires consistent independent study, regular quantitative problem solving, and careful interpretation of energy-band diagrams and device characteristics. Students are expected to review assigned textbook sections and lecture materials before class. After each session, students should consolidate their notes, reproduce key derivations, and solve assigned problems. Particular attention should be given to identifying the relevant semiconductor-physics model, applying equations with correct assumptions and units, interpreting I–V and C–V graphs, and relating mathematical results to the underlying device physics. Passing requirement (pass/fail) The course follows the grading regulations of the School of Science and Engineering. Undergraduate students must achieve an overall course result of at least 60% to pass. A failing result is handled in accordance with applicable University regulations governing course repetition or reassessment. Cheating/plagiarism Academic dishonesty, including cheating, plagiarism, unauthorized collaboration, copying another student's work, or using unauthorized materials or devices during an assessment, is prohibited. A confirmed violation in a quiz, midterm examination, final examination, or other assessed work will be handled according to University academic-integrity rules and may result in a score of zero (0) for the affected assessment. Generative AI Policy Generative AI tools may be used as learning aids for concept clarification, study organization, practice-question generation, and formative feedback. They may not be used to generate or complete answers for quizzes, examinations, or other assessed work unless explicitly authorized by the instructor. Students are responsible for checking the scientific accuracy of AI-generated device equations, energy-band diagrams, numerical calculations, units, assumptions, plots, fabrication information, and references. Permitted AI use in assessed work		

must be appropriately acknowledged.

Professional behavior guidelines

Students are expected to maintain a respectful, constructive, and academically focused environment. They should arrive on time, be prepared for class and laboratory activities, participate appropriately, follow the instructor's directions, and observe relevant laboratory and equipment-safety requirements. Unauthorized conversations, disruptive conduct, unethical behavior, and inappropriate use of electronic devices are not permitted during instructional activities.

Attendance

Students who maintain full attendance throughout the semester will receive 5 attendance marks. For every three recorded absences, 1 attendance mark will be deducted, subject to University attendance regulations. Students remain responsible for material, announcements, assignments, and laboratory instructions missed during an absence.

Quizzes

Four quizzes will be administered during the semester. Quiz dates will normally be announced in class approximately two weeks in advance. Quizzes will assess conceptual understanding, energy-band interpretation, device characteristics, and quantitative problem-solving skills and will be based primarily on lecture content, assigned readings, and homework problems.

Activity

Up to 10 activity marks may be earned through meaningful academic participation during the semester. Credit may be awarded for explaining semiconductor concepts, constructing and interpreting band diagrams, solving seminar problems, analyzing I-V or C-V characteristics, participating effectively in laboratory work, and presenting logically structured reasoning rather than merely stating a numerical result.

Tentative Schedule

Week	Date/Day (tentative)	Topics	Textbook/Assignments
1.	17.09.26	SEMICONDUCTOR MATERIALS, ENERGY BANDS, AND IC TECHNOLOGY Semiconductor materials; allowed and forbidden energy bands; energy-band and bond models; electron effective mass and hole concept; metals, insulators, and semiconductors; integrated-circuit overview and introductory fabrication concepts. Problem solving	[1] Prologue, pp. xix–xxiii; Ch. 1, §1.1, p. 1; Ch. 3, §§3.1–3.2.5, pp. 59–82 [4] Instructor handnotes
2.	24.09.26	THE SEMICONDUCTOR IN EQUILIBRIUM Equilibrium electrons and holes; intrinsic carrier concentration and intrinsic Fermi level; dopant atoms and energy levels; extrinsic semiconductors; donor/acceptor statistics; charge neutrality; Fermi-level dependence on doping and temperature. Problem solving	[1] Ch. 4, §§4.1–4.6, pp. 107–147 [4] Instructor handnotes
3.	01.10.26	CARRIER TRANSPORT PHENOMENA Carrier drift; mobility effects; conductivity and velocity saturation; carrier diffusion; total current density;	[1] Ch. 5, §§5.1–5.4, pp. 157–183 [4] Instructor handnotes

		graded impurity distributions; Einstein relation; Hall effect. Problem solving	
4.	08.10.26	NONEQUILIBRIUM EXCESS CARRIERS IN SEMICONDUCTORS Carrier generation and recombination; continuity and time-dependent diffusion equations; ambipolar transport; quasi-Fermi energy levels; excess-carrier lifetime; Shockley–Read–Hall recombination; surface effects. Problem solving	[1] Ch. 6, §§6.1–6.6, pp. 193–231 [4] Instructor handnotes
5.	15.10.26	THE p–n JUNCTION Basic junction structure; zero-bias equilibrium; built-in potential barrier; electric field and space-charge width; reverse bias; junction capacitance; one-sided and nonuniform junctions; junction breakdown. Problem solving	[1] Ch. 7, §§7.1–7.5, pp. 242–267 [4] Instructor handnotes
6.	22.10.26	THE p–n JUNCTION DIODE Carrier flow and ideal diode current; boundary conditions and minority-carrier distributions; temperature effects; generation–recombination and high-injection currents; small-signal model; charge storage and diode transients. Problem solving	[1] Ch. 8, §§8.1–8.4, pp. 277–317 [4] Instructor handnotes
7.	29.10.26	METAL–SEMICONDUCTOR CONTACTS AND HETEROJUNCTIONS Schottky barrier diode; ideal and nonideal barrier properties; Schottky I–V characteristics; ohmic contacts and specific contact resistance; heterojunction materials, energy-band diagrams, two-dimensional electron gas, and interface electrostatics. Problem solving	[1] Ch. 9, §§9.1–9.3, pp. 332–363 [4] Instructor handnotes
8.	05.11.26	MOS CAPACITORS AND BASIC MOSFET OPERATION MOS energy-band diagrams; depletion layer and surface charge; work-function difference; flat-band and threshold voltage; ideal and nonideal C–V characteristics; MOSFET structures; I–V relationships; transconductance and substrate-bias effects. Problem solving	[1] Ch. 10, §§10.1–10.3.5, pp. 372–421 [4] Instructor handnotes
	TBC	MIDTERM EXAM Midterm examination and review/problem-solving activities as announced by the instructor.	
9.	12.11.26	MOSFET NONIDEAL EFFECTS AND SCALING Channel-length modulation; mobility variation; velocity saturation and ballistic transport; constant-field and generalized scaling; short- and narrow-channel effects; breakdown; threshold adjustment; radiation and hot-electron effects. Problem solving	[1] Ch. 11, §§11.1–11.5, pp. 444–481 [4] Instructor handnotes

10.	19.11.26	BIPOLAR TRANSISTOR BJT action and modes of operation; amplification; minority-carrier distributions; transistor currents and current gain; nonideal effects; equivalent-circuit models; frequency limitations; large-signal switching; selected advanced BJT structures. Problem solving	[1] Ch. 12, §§12.1–12.8, pp. 492–558 [4] Instructor handnotes
11.	26.11.26	JFET, MESFET, AND HEMT Basic pn-JFET and MESFET operation; pinch-off and saturation; ideal DC I–V relationships; transconductance; nonideal effects and frequency limitations; high-electron-mobility transistor and quantum-well concepts. Problem solving	[1] Ch. 13, §§13.1–13.5, pp. 572–608 [4] Instructor handnotes
12.	03.12.26	OPTOELECTRONIC DEVICES Optical absorption and electron–hole pair generation; solar cells; photoconductors and photodiodes; PIN and avalanche photodiodes; phototransistors; photoluminescence and electroluminescence; LEDs and laser diodes. Problem solving	[1] Ch. 14, §§14.1–14.6, pp. 619–660 [4] Instructor handnotes
13.	10.12.26	SEMICONDUCTOR MICROWAVE AND POWER DEVICES Tunnel, Gunn, and IMPATT diodes; power bipolar transistors; power MOSFET structures and characteristics; thyristor operation and triggering; selected IGBT and wide-bandgap power-device concepts. Problem solving	[1] Ch. 15, §§15.1–15.6, pp. 671–700 [4] Instructor handnotes
14.	17.12.26	DEVICE NOISE Thermal, shot, and flicker noise; physical noise sources and noise reduction; modern device perspectives including high-k/metal-gate integration, FinFET/GAAFET concepts, wide-bandgap GaN and SiC devices, tunnel FETs, nanoscale devices, and selected quantum-device concepts. Problem solving and course review	[1] Background: Ch. 11, §§11.2–11.5, pp. 455–481; Ch. 13, §13.5, pp. 602–608; Ch. 15, §§15.1–15.6, pp. 671–700 [4] Instructor hand notes
15.	24.12.26	EMERGING SEMICONDUCTOR TECHNOLOGIES Nanoscale devices, and selected quantum-device concepts. Problem solving and course review	[1] §§15.1–15.6, pp. 671–700 [4] Instructor hand notes
	TBC	Final exam	