SEMICONDUCTOR ENGINEERING AND PHYSICS

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OVERVIEW

The Certificate of Graduate Study in Semiconductor Engineering and Physics (CGS-SEP) program aims to expand the depth of instruction in semiconductor-related areas for students who are pursuing graduate degrees in electrical or mechanical engineering, materials science, as well as physics or chemistry. It is also highly suitable for people already working in the industry who want to broaden their experience in other areas of semiconductor technology.

DEGREES

Semiconductor Engineering and Physics CGS

FACULTY

Frolik, Jeff L.; Professor, Department of Electrical and Biomedical Engineering; PHD, University of Michigan Ann Arbor
Headrick, Randall L.; Professor, Department of Physics; PHD, University of Pennsylvania

Electrical Engineering Courses

EE 5310. Power System Analysis. 3 Credits.
Transmission system modeling, operations and planning and energy policy are discussed to prepare students for the electricity and energy industry and power/energy systems research. Topics include: transmission line models, generator capability curves, transformer modeling and control, per-unit conversion, power flow calculations and software, smart grid. Prerequisite: Graduate Electrical Engineering student or Instructor permission.

EE 5410. Digital VLSI Circuit Design. 0 or 3 Credits.
Covers the techniques for the design, analysis and layout of digital CMOS circuits and systems. Major topics include MOSFET basics (structure and behavior of a MOSFET, CMOS fabrication, and design rules), detailed analysis of the CMOS circuits and systems (static behavior, ratioed vs. ratioless design), noise margins, computing rise and fall times, delay models, resistance. Prerequisite: Electrical Engineering Graduate student or Instructor permission. Cross-listed with: CMPE 5410.

EE 5430. RF Circuit Design. 3 Credits.
Design and analysis of radio frequency and microwave circuits. Covers radio frequency and microwave behavior of passive components, various transmission line structures, electromagnetic (EM) wave propagation in dielectric media, reflection coefficient and load impedance, network properties and applications, impedance matching network design, scattering parameters and their usage for RF. Prerequisite: Electrical Engineering Graduate student or Instructor permission.

EE 5440. Gr Semiconductor Materials/Dev. 0 or 4 Credits.
Covers energy band theory, effective mass, band structure and electronic properties of semiconductors. Transport of electrons and holes in bulk materials and across interfaces. MOSFETs, BJTs, pn junctions, and Schottky barriers. Experimental portion of course will have a laboratory component for electronic measurements of semiconductor devices. Credit not awarded for both EE 5440 and EE 3440. Prerequisite: Graduate student or Instructor permission. Cross-listed with: PHYS 5675.

EE 5460. Microelec. Circuit Fabrication. 0 or 4 Credits.
Provides a firm knowledge base in modern semiconductor fabrication technology. This technology lies at the heart of all modern computer and communication systems. Analyze and evaluate the unit processes involved in creating semiconductor chips such as photolithography, plasma etch, ion implant and metallization. Explore the current state-of-the-art and demonstrate how these building blocks affect the electrical behavior of semiconductor devices. Prerequisites: Electrical Engineering, Materials Science, Mechanical Engineering, or Physics Graduate student; or Instructor permission. Cross-listed with: PHYS 5165.

EE 5503. Modern Signal Processing. 3 Credits.
Covers principles and methods for digital signal processing. The analysis and design of discrete-time systems as signal processing devices is provided in the context of filter design, adaptive processing, compress sensing, and topics on image processing. Topics covered: quantization, reconstruction of signals, z-transform, FIR/IIR, compress sensing, compress sensing processing, intro to images, pixel and region-based classification, and segmentation, among others.

EE 5540. Real-Time Control Systems. 3 Credits.
Digital control systems analysis and design. Topics include: difference equations, the Z-transforms, discrete-time transfer functions, state-space models, sampled-data systems, discretization, real-time control, microprocessor implementation, and optimal control. Project-based final. Prerequisite: Electrical Engineering Graduate student or Instructor permission. Cross-listed with: CMPE 5540.

EE 5550. Autonomy I. 3 Credits.
Students learn how to make engineered systems autonomous/intelligent. Covers logic and algorithms, real-time estimation and control of dynamical systems, optimization and optimal planning, path planning for robots and autonomous vehicles, basics of artificial intelligence and machine learning, and ethics of automation. Applications include hover flight of quadrotor drones, perception and navigation of robots including robotic arms and self-driving vehicles, and autonomous control of the power grid. Prerequisites: Graduate student or Instructor permission; content knowledge of control systems (such as EE 3515) assumed.

EE 5560. Autonomy II. 3 Credits.
Covers principles and methods for perception and localization of autonomous robotic systems within a systematic software framework. The analysis and design of practical methods for the deployment of control, path planning, localization and mapping, and safety of autonomous systems are provided in the context of the Robotic Operative Systems (ROS). Topics covered: introduction to ROS; perception using RGB-D cameras and lidar; Kalman filters for state estimation; SLAM; and path planning of robotic manipulators. Prerequisite: EE 5550.

EE 5610. Information Theory. 3 Credits.
Introduction to probability concepts of information theory; entropy of probability models; theoretical derivations of channel capacity; coding methods and theorems, sampling theorems. Prerequisite: Graduate student or Instructor permission. Cross-listed with: CS 5610, CMPE 5610.

EE 5810. Digital Computer Design. 3 Credits.
To gain a solid understanding of digital computer operating mechanisms and reconfigurable computing, and advance into hands-on experiences to design and debug digital computer system and embedded system. Field programmable gate arrays (FPGAs) will be utilized as the development platform. Prerequisite: Electrical Engineering Graduate student, Computer Science Graduate student, or Instructor permission. Cross-listed with: CMPE 5810, CS 5810.

EE 5915. Advanced Circuit Applications. 3 Credits.
Analog and digital circuit applications. Topics may include analog to digital converters, operational amplifiers, optical isolators (linear and non-linear), comparators, voltage to frequency converters, analog switches, voltage references, precision dividers, analog multipliers, multiplexers, phase locked loops, power supply monitoring circuits, instrumentation amplifiers and pulse width modulators. Prerequisites: Electrical Engineering Graduate student or Instructor permission; Knowledge of material in EE 3110 Electronics I.

EE 5990. Special Topics. 1-18 Credits.
See Schedule of Courses for specific titles.

EE 5993. Independent Study. 1-18 Credits.
A course which is tailored to fit the interests of a specific student, which occurs outside the traditional classroom/laboratory setting under the supervision of a faculty member, for which credit is awarded. Offered at department discretion.

EE 6110. System Theory. 3 Credits.
Linear vector spaces. State equations and solution. Diagonalization and Jordan canonical form. Orthogonal and biorthogonal projections. Quadratic forms. Spectral resolution. Principal component analysis, singular value decomposition and Karhunen-Loeve transform. Compressive sensing. Prerequisites: MATH 3230 or MATH 3201; MATH 2544; EE 3150 or ME 2120.

EE 6120. Stochastic Processes. 3 Credits.
Probability theory, random variables and stochastic processes. Response of linear systems to random inputs. Applications in engineering. Prerequisites: Graduate student in CEMS or Instructor permission.

EE 6130. Convex Optimization. 3 Credits.
Provides advanced mathematical tools to recognize optimization problems from applications, presents rigorous theory of convex optimization with an emphasis on results that are helpful for implementation/computation/modeling, providing student with the experience and understanding necessary to use the tools in their own research work or applications. Prerequisites: Linear Algebra, multi-variable calculus.

EE 6391. Master's Thesis Research. 1-18 Credits.

EE 6392. Master's Project Research. 1-3 Credits.
Master's Project.

EE 6520. Nonlinear System Theory. 3 Credits.
Basic nonlinear methods including computational and geometrical techniques for analysis of nonlinear systems. Describing function methods and bifurcation and catastrophe theory. Sensitivity and stability considerations. Prerequisite: MATH 3230 or MATH 3201. Pre/Co-requisite: EE 6110 recommended.

EE 6530. Estimation Theory. 3 Credits.
Foundations of linear and nonlinear least squares estimation, smoothing and prediction, computational aspects, Kalman filtering, nonlinear filtering, parameter identification, and adaptive filtering. Applications to students' research. Pre/co-requisite: STAT 2510.

EE 6990. Special Topics. 1-18 Credits.
Advanced topics of current interest in Electrical Engineering. Prerequisite: Instructor permission.

EE 6991. Internship. 1-18 Credits.
On-site supervised work experience combined with a structured academic learning plan directed by a faculty member or a faculty-staff team in which a faculty member is the instructor of record, for which academic credit is awarded. Offered at department discretion.

EE 6993. Independent Study. 1-18 Credits.
A course which is tailored to fit the interests of a specific student, which occurs outside the traditional classroom/laboratory setting under the supervision of a faculty member, for which credit is awarded. Offered at department discretion.

EE 6995. Graduate Independent Research. 1-18 Credits.
Graduate student work on individual or small team research projects under the supervision of a faculty member, for which credit is awarded. Offered at department discretion.

EE 7491. Doctoral Dissertation Research. 1-18 Credits.
Research for the Doctoral Dissertation.

EE 7990. Special Topics. 1-18 Credits.
See Schedule of Courses for specific titles.

EE 7991. Internship. 1-18 Credits.
On-site supervised work experience combined with a structured academic learning plan directed by a faculty member or a faculty-staff team in which a faculty member is the instructor of record, for which academic credit is awarded. Offered at department discretion.

EE 7995. Graduate Independent Research. 1-18 Credits.
Graduate student work on individual or small team research projects under the supervision of a faculty member, for which credit is awarded. Offered at department discretion.

Materials Science Courses

MATS 5185. Nano-analysis of Materials. 1 Credit.
Explores the theory and practical operation of advanced techniques to analyze the structure, composition, and surfaces of micro and nano-scale materials. Students will be trained as users of a Field Emission Scanning Electron Microscope (FESEM) including x-ray elemental analysis. Credit not awarded for both PHYS 3175 and PHYS 5185. Prerequisite: Graduate student in Physics, Materials Science, or related program, or Instructor permission. Cross-listed with: PHYS 5185.

MATS 5610. Gr Chemical Thermodynamics. 3 Credits.
Calculus-based exploration of the fundamental principles of thermodynamics (gases, equilibrium, free energy, laws of thermodynamics, statistical thermodynamics, phase transitions, mixtures, chemical reactions, solids), from an interdisciplinary perspective. This topic is a cornerstone of many scientific and engineering disciplines. Appropriate for students in Chemistry and other STEM fields. Prerequisites: Graduate student or Instructor permission; content knowledge of general chemistry, calculus, and introductory physics (mechanics) assumed. Cross-listed with: CHEM 5610.

MATS 5625. Structure&Bonding of Materials. 3 Credits.
Study of atomic and molecular bonding, the structure of materials, and their associated properties. Explores how structures and bonding types influence the electrical, thermal, mechanical, and optical properties of materials. Covers topics such as primary and secondary bonding mechanisms, crystallography, diffraction techniques, and the properties of metals, ceramics, polymers, and biological materials. Prerequisites: Graduate student in Physics, Materials Science, or related program, or Instructor permission. Cross-listed with: PHYS 5625.

MATS 6391. Master's Thesis Research. 1-18 Credits.
Research for the Master's Thesis.

MATS 6990. Special Topics. 1-18 Credits.
See Schedule of Courses for specific titles.

MATS 6991. Internship. 1-18 Credits.
On-site supervised work experience combined with a structured academic learning plan directed by a faculty member or a faculty-staff team in which a faculty member is the instructor of record, for which academic credit is awarded. Offered at department discretion.

MATS 6995. Graduate Independent Research. 1-18 Credits.
Graduate student work on individual or small team research projects under the supervision of a faculty member, for which credit is awarded. Offered at department discretion.

MATS 7491. Doctoral Dissertation Research. 1-18 Credits.
Research for the Doctoral Dissertation.

MATS 7990. Special Topics. 1-18 Credits.
See Schedule of Courses for specific titles.

MATS 7991. Internship. 1-18 Credits.
On-site supervised work experience combined with a structured academic learning plan directed by a faculty member or a faculty-staff team in which a faculty member is the instructor of record, for which academic credit is awarded. Offered at department discretion.

MATS 7995. Graduate Independent Research. 1-18 Credits.
Graduate student work on individual or small team research projects under the supervision of a faculty member, for which credit is awarded. Offered at department discretion.

Physics Courses

PHYS 5125. Mathematical Physics. 3 Credits.
Introduction to basic mathematical methods of theoretical physics; vector and tensor analysis, partial differential equations, orthogonal functions, complex variables and variational techniques. Prerequisites: Graduate student or undergraduate student with Instructor permission; knowledge of PHYS 2200 and PHYS 4300 topics strongly recommended.

PHYS 5165. Microelec. Circuit Fabrication. 0 or 4 Credits.
Provides a firm knowledge base in modern semiconductor fabrication technology. This technology lies at the heart of all modern computer and communication systems. Analyze and evaluate the unit processes involved in creating semiconductor chips such as photolithography, plasma etch, ion implant and metallization. Explore the current state-of-the-art and demonstrate how these building blocks affect the electrical behavior of semiconductor devices. Prerequisites: Electrical Engineering, Materials Science, Mechanical Engineering, or Physics Graduate student; or Instructor permission. Cross-listed with: EE 5460.

PHYS 5185. Nano-analysis of Materials. 1 Credit.
Explores the theory and practical operation of advanced techniques to analyze the structure, composition, and surfaces of micro and nano-scale materials. Students will be trained as users of a Field Emission Scanning Electron Microscope (FESEM) including x-ray elemental analysis. Credit not awarded for both PHYS 3175 and PHYS 5185. Prerequisite: Graduate student in Physics, Materials Science, or related program, or Instructor permission. Cross-listed with: MATS 5185.

PHYS 5200. Advanced Dynamics. 3 Credits.
Classical mechanics presented as the basis of the concepts and methods of modern physics. Variational, Lagrangian, and Hamiltonian formulations, canonical transformations, continuous systems. Prerequisite: Graduate student or undergraduate student with Instructor permission; knowledge PHYS 2200 topics strongly recommended.

PHYS 5300. Electromagnetic Theory. 3 Credits.
Development of Maxwell's theory of electromagnetism emphasizing its physical basis and the modes of mathematical description. Prerequisite: Graduate student or undergraduate student with Instructor permission; knowledge of PHYS 4300 topics strongly recommended.

PHYS 5400. Statistical Mechanics. 3 Credits.
Following a review of thermodynamics, covers the fundamentals of classical and quantum statistical mechanics including ensembles, identical particles, Bose and Fermi statistics, phase-transitions and critical phenomena, renormalization group, irreversible processes and fluctuations. Prerequisite: Graduate student or undergraduate student with Instructor permission; knowledge of PHYS 3400 topics strongly recommended.

PHYS 5500. Quantum Mechanics II. 3 Credits.
Mathematical and physical foundations of nonrelativistic quantum mechanics from the unifying point of view of Dirac. Symmetry operations and the algebraic structure of quantum mechanics are emphasized. Prerequisite: Graduate student or undergraduate student with Instructor permission; knowledge of PHYS 3400 topics strongly recommended.

PHYS 5625. Structure&Bonding of Materials. 3 Credits.
Study of atomic and molecular bonding, the structure of materials, and their associated properties. Explores how structures and bonding types influence the electrical, thermal, mechanical, and optical properties of materials. Covers topics such as primary and secondary bonding mechanisms, crystallography, diffraction techniques, and the properties of metals, ceramics, polymers, and biological materials. Prerequisites: Graduate student in Physics, Materials Science, or related program, or Instructor permission. Cross-listed with: MATS 5625.

PHYS 5675. Gr Semiconductor Materials/Dev. 0 or 4 Credits.
Covers Energy band theory, effective mass, band structure and electronic properties of semiconductors. Transport of electrons and holes in bulk materials and across interfaces. MOSFETs, BJTs, pn junctions, and Schottky barriers. Experimental portion of course will have a laboratory component for electronic measurements of semiconductor devices. Credit not awarded for both PHYS 5675 and PHYS 3675. Prerequisite: Graduate student or Instructor permission. Cross-listed with: EE 5440.

PHYS 5990. Special Topics. 1-18 Credits.
See Schedule of Courses for specific titles. Prerequisites: Department permission, Graduate student.

PHYS 6000. Teaching of College Physics. 1 Credit.
Instructional strategies and techniques with application to the teaching of laboratories and recitations. Prerequisites: Undergraduate degree in Physics; Instructor permission.

PHYS 6391. Master's Thesis Research. 1-18 Credits.
Research for the Master's Thesis.

PHYS 6990. Special Topics. 1-18 Credits.
See Schedule of Courses for specific titles.

PHYS 6991. Internship. 1-18 Credits.
On-site supervised work experience combined with a structured academic learning plan directed by a faculty member or a faculty-staff team in which a faculty member is the instructor of record, for which academic credit is awarded. Offered at department discretion.

PHYS 6993. Independent Study. 1-18 Credits.
A course which is tailored to fit the interests of a specific student, which occurs outside the traditional classroom/laboratory setting under the supervision of a faculty member, for which credit is awarded. Offered at department discretion.

PHYS 6994. Teaching Assistantship. 1-3 Credits.
Student service as a teaching assistant, usually in an introductory level course in the discipline, for which credit is awarded. Offered at department discretion.

PHYS 6995. Graduate Independent Research. 1-18 Credits.
Graduate student work on individual or small team research projects under the supervision of a faculty member, for which credit is awarded. Offered at department discretion.

PHYS 7491. Doctoral Dissertation Research. 1-18 Credits.
Research for the Doctoral Dissertation.

PHYS 7990. Special Topics. 1-18 Credits.
See Schedule of Courses for specific titles.

PHYS 7991. Internship. 1-18 Credits.
On-site supervised work experience combined with a structured academic learning plan directed by a faculty member or a faculty-staff team in which a faculty member is the instructor of record, for which academic credit is awarded. Offered at department discretion.

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