

Contents

EE MSE Comprehensive Exam Overview	1
Control systems.....	2
Electromagnetics, antennas and microwave circuits.....	3
Electronic and mixed-signal circuit design	4
Electric Power and Energy Systems.....	5
Physical Electronics and Photonics	6
Signal processing and communications systems	7
Appendices- Study topics by courses	8
Appendix 1- Study topics by course for Electronic and mixed-signal circuit design.....	8
Appendix 2- Study topics by course for Electric Power and Energy Systems	9
Appendix 3- Study topics by course for Physical Electronics and Photonics.....	12

EE MSE Comprehensive Exam Overview

The EE MSE program requires a comprehensive examination, which is quite general in nature. It is administered on the sixth Friday of the semester, consists of a written exam in the major area of study, and covers material through the master's degree level. The ECEE area committee makes up the written exam.

The student must sign up for the exam by submitting the MSE Comprehensive Exam Sign Up to the ECEE graduate advising office by the end of the second week of classes. Before taking this exam, the student must have an approved Plan of Study with Graduate College.

- The exam takes three hours. A grade of 60% or more is required to pass this exam.
- Any student failing the exam may petition to attempt it a second time. There is no guarantee that the petition will be accepted. A third exam will not be permitted.
- Students should save all course material from their courses, as they might not retain access to the canvas sites for those courses after the course is complete

A description of the exam for each of the six major areas of study appears on the following pages. Appendices at the end of the guide contain study topics by course for certain areas of specialization. The six major areas of study are:

- Control systems
- Electromagnetics, antennas and microwave circuits
- Electronic and mixed-signal circuit design
- Electric power and energy systems
- Physical Electronics and Photonics
- Signal processing and communications

Control systems

Closed book

Calculators are allowed

The exam covers undergraduate and graduate controls classes taken by the students in the exam. Typically, the topics covered are:

2 questions from EEE 480/591

2 questions from EEE 481/591

2 questions from EEE 582

1 question from EEE 587

1 question from EEE 586

1 question from EEE 511/Random Processes

1 question from EEE 588 or EEE 586 or EEE 587

The choices of last two problems depend on the student background.

Out of the ten questions the students should answer 7 correctly to receive full marks (100%). The passing grade is 60%.

To view sample problems, please be sure to be logged into your MyASU account to access this link. You must be logged into your MyASU account. [Controls Sample Problems](#).

Electromagnetics, antennas and microwave circuits

Closed book, Closed notes exam

Hand calculators allowed; NO laptops

No 'cheat' sheets with equations or any other material

1. Ten problems will be made available, but student can only attempt/choose seven
2. Each of the seven attempted/chosen problems is graded on the basis of 10 (maximum)
3. The maximum score you can get is 70; passing grade is 42 (60% of 70)
4. Questions/problems covering undergraduate electromagnetics classes (EEE 241 and EEE 341)
5. Questions/problems from the 400-level and 500-level electromagnetic classes taken from the POSs of those attempting the exam
6. Therefore, because of 5, each student taking the MSE exam most likely will not have taken all the classes from which problems are selected

Electronic and mixed-signal circuit design

Closed book exam
Calculators allowed

Courses covered:

- EEE 425/591 - Digital Systems and Circuits
- EEE 433/591 - Analog Integrated Circuits
- EEE 523 - Advanced Analog Integrated Circuits
- EEE 525 - VLSI Design

There will be three questions from each course. Students choose any eight questions to answer. To pass the exam, a score of 60% or better is required. Practice exams are not available.

See Appendix 1 for specific study topics by course.

Electric Power and Energy Systems

1. Closed book exam
2. No notes or handbooks
3. Calculators only (use of cell phones or computer tablets is prohibited)
4. The questions on the exam will be basic questions such that any MSE power student, who has taken the corresponding class, should be able to answer the question

The MSE exam will have a **Section A** and a **Section B**. **Students must answer a total of exactly seven (7) questions with at least three (3) from Section A and at least three (3) from Section B of the MSE Comprehensive Exam.**

Section A: Section A will cover 3 core classes: EEE 572 Advanced Power Electronics, EEE 577 Power System Operations and Planning, and EEE 579 Transmission and Distribution. There will be two (2) questions corresponding to each class giving Section A six (6) questions in total.

Section B: When signing up for the MSE Comprehensive Exam, each student will select between a minimum of four (4) and a maximum of six (6) power classes from those listed in Table 1. Each class selected by the student will have one (1) corresponding question in Section B.

Table 1. List of Power Area Classes for Section B.

EEE 562 - Reactor Theory and Design	EEE 576 - Power System Dynamics
EEE 563 - Reactor Dynamic and Diagnostics	EEE 598_1 - Renewable Electric Energy Systems
EEE 564 - Nuclear Power Operation	EEE 598_2 - Electric Energy Markets
EEE 571 - Power System Transients	EEE 598_3 - WAMS Applications in Power Systems
EEE 573 (Not available for Spring or Fall 2022 exam)	EEE 598_4 - Machine Learning for Power Systems (or Machine Learning for Smart Grids)
EEE 574 (Not available for Spring 202 exam)	EEE 598_5 - Resilient Smart Electric Grids
EEE 575 - Power System Stability	EEE 598_6 - Power System Reliability

Please note that EEE 591 courses are not listed above. EEE 591 content is typically at the undergraduate level and these courses are not considered as sufficient preparation for the MSE Comprehensive Exam.

A total score of at least 420/700 is needed to pass the MSE Comprehensive Exam.

To view sample problems, please be sure to be logged into your MyASU account to access this link. You must be logged into your MyASU account. [Fall 2018 sample problems](#) and [Spring 2019 sample problems](#). See Appendix 2 for specific study topics by course.

Physical Electronics and Photonics

Closed book

Calculators are allowed

Students must choose 4 classes to be tested on:

Students choose minimum 3 of the 7 Solid-State Electronics Graduate classes highlighted in red (core courses) + 1 or less from the 591 classes the equivalents of which are listed in the Physical Electronics and Photonics Undergraduate classes.

- Also, students can choose only one from 465 and 565.
- Students can choose only one from 531 and 436.
- Students can choose only one from 437 and 537.
- 598 classes will not be allowed for selection.
- Professor chosen to prepare the exam might not necessarily be the professor that taught the class.
- Students will be given 12 questions (3 questions per class selected to be tested on), and 8 questions must be answered.

List of Solid-State Electronics Graduate Classes (Classes marked in red are core courses)

530 Advanced Silicon Processing

531 Semiconductor Device Theory I

532 Semiconductor Device Theory II

533 Semiconductor Device/Process Simulation

534 Semiconductor Transport

535 Electron Transport in Nanostructures

536 Semiconductor Characterization

537 Semiconductor Optoelectronics

539 Fundamentals of Solid-State Electronics

565 Solar Cells

List of Solid-State Electronics Undergraduate Classes that can be taken as EEE591 Courses

434 Quantum Mechanics for Engineers

435 Fundamentals of CMOS and MEMS

436 Fundamentals of Solid-State Devices

437 Optoelectronics

439 Semiconductor Facilities and Cleanroom Practices

465 Photovoltaic Energy Conversion

See Appendix 2 for specific study topics by course.

Signal processing and communications systems

The test is composed of two parts. Students must work four questions from Part 1, and three questions from Part 2.

Students may use a calculator, but no other reference material.

Courses normally covered in Part 1

- EEE 203 Signals and Systems (1 question)
- EEE 350 Random Signal Analysis (1 question)
- EEE 404 Real-Time DSP (1 question)
- EEE 407 Digital Signal Processing (2 questions)
- EEE 455 Communication Systems (2 questions)

Courses normally covered in Part 2 (1 question per course)

- EEE 459 Communication Networks
- EEE 505 Time-Frequency Signal Processing
- EEE 506 Digital Spectral Analysis
- EEE 507 Multidimensional Signal Processing
- EEE 508 Digital Image/Video Processing and Compression
- EEE 510 Multimedia Signal Processing
- EEE 551 Information Theory
- EEE 552 Digital and Wireless Communications (formerly called Digital Communications)
- EEE 554 Random Signal Theory
- EEE 557 Broadband Networks
- EEE 558 Recent Advancements in Communications (formerly Wireless Communications)

To view sample problems, please be sure to be logged into your MyASU account to access this link. You must be logged into your MyASU account. [Fall 2017](#), [Spring 2018](#), and [Fall 2018](#).

Appendices- Study topics by courses

Appendix 1- Study topics by course for Electronic and mixed-signal circuit design

EEE 425/591 - Digital Systems and Circuits

- a. CMOS operation and analysis
- b. Logic gate timing and logical efforts
- c. Sequential circuits
- d. Arithmetic circuits
- e. Interconnect Analysis

EEE 433/591 - Analog Integrated Circuits

- f. Common gate, source, and drain amplifiers
- g. Two stage Miller compensated operational amplifier

EEE 523 - Advanced Analog Integrated Circuits

- h. Fully differential, class AB and cascode amplifiers, common-mode feedback
- i. Bandgap voltage references
- j. Noise, PSRR, CMRR in analog circuits
- k. Switched capacitor circuits

EEE 525 - VLSI Design

- l. ALU and datapath circuits
- m. Synchronous design and timing
- n. Memory Circuits
- o. Low-power design

Appendix 2- Study topics by course for Electric Power and Energy Systems

EEE 579: Power Transmission and Distribution

- High-voltage transmission line design
- Transmission line parameter calculation
- Transmission protection
- Distribution system design and operation
- Smart grid

EEE 577

- Basics of characteristics of generators
- Transmission system modeling, power flow, shift factors/power transfer distribution factors
- Economic dispatch, optimal power flow, and unit commitment
- Power system security, power system reliability requirements, and ancillary services
- Generation control

EEE 572 Advanced Power Electronics

- Basic principles of switch mode power conversion including converters with isolation
- Detailed analysis (waveforms, input-output relationships, ripple content etc.) of various DC-DC converters including isolated converters
- Phasor analysis and switching frequency analysis of dc-ac and ac-dc converters
- Design of power converters; basic control design for DC-DC converters
- Power converter topologies and schematics for various applications

EEE 562

- Quantification of neutron chain reacting systems
- Determination of neutron reaction rates
- Solution of the one-speed neutron diffusion equation for a variety of situations
- Analysis of nuclear reactor core steady-state thermal performance

EEE 563

- Calculation of kinetics parameters for a zero power reactor
- Solution of the point kinetics equations for various reactivity insertions
- Quantification of reactivity feedback mechanisms
- Analysis of the effects of fuel depletion and fission product poisons

EEE 564

- Nuclear power plants and reactor safety systems
- Reactor startup and power range operations
- Probabilistic risk assessment

EEE 571

- Single phase circuit transient analysis using direct Laplace method
- Three phase circuit transient analysis using direct Laplace method
- Travelling waves analysis for transient of transmission line

- Travelling waves analysis for lightning events
- Short-circuit protection using breakers

598 Renewable Electric Energy Systems

- Average models and phasor analysis of micro, string and central PV inverters including various subsystems
- Switching level analysis of single-phase and three-phase converters
- Design of PV inverters
- Operating principles, analysis and control design for doubly-fed induction generator based wind generators

598 - Reliability

- Frequency balance approach for reliability analysis;
- Methods of quantitative reliability analysis;
- Generation system reliability;
- Multi-area power system reliability;
- Composite power system reliability evaluation.

EEE 598 Electric Energy Markets

- Basics of economics: supply and demand, market power, game theory
- Linear optimization: primal and dual, strong duality, complementary slackness
- Power system economics: linearized optimal power flow and unit commitment scheduling
- Uniform versus pay-as-bid pricing
- Locational marginal prices
- Dual of the dcopf; market analysis
- Convex markets versus non-convex markets; uplift payments
- Financial transmission rights
- Ancillary services

EEE-598: WAMS-based Applications in Power Systems

- Investigate role of advanced instrumentation in monitoring, protection, and control of power systems
- Analyze effects of instrument transformers, signal conditioning circuits, A/D and DSP chips, time synchronization and sampling, output circuits and devices, and communication channels
- Implement state-of-the-art algorithms related to synchrophasor data by computer software

EEE 598 - Machine Learning for Smart Grid

- Probability and Optimization
- Unsupervised Learning and Supervised Learning
- Semi-supervised Learning and Reinforcement learning
- Deep Learning
- Applications to Smart Grid

EEE 598 – Resilient Smart Electric Grids

- Definition of resiliency of electric power grids, resiliency indicators, and resiliency metrics
- Smart grid: resiliency challenges and opportunities
- Distributed energy resources: unique characteristics and opportunities to enhance power system resiliency
- Measures to enhance resiliency of bulk power systems

Appendix 3- Study topics by course for Physical Electronics and Photonics

List of Solid-State Electronics Graduate Classes (**Classes marked in red are core courses**)

530 Advanced Silicon Processing (Kozicki)

- Device scaling, ICs as systems, and economics of fabrication
- Silicon – crystal growth
- Device sub-structures and interfaces, MOS transistor operation
- Diffusion
- Oxidation
- Chemical vapor deposition
- Ion implantation
- Dry etch
- Sputtering
- Resist properties and exposure tools
- Interconnect
- Process control and yield
- Memory

531 Semiconductor Device Theory I (Hongbin Yu, Ivan Sanchez Esqueda)

- Semiconductor energy-band diagram
- concepts: DOS, Fermi function, carrier density
- drift-diffusion equations
- pn junction ideal current equation
- MOS electrostatics, basic MOSFET I-V characteristics

532 Semiconductor Device Theory II (Vasileska)

- Heterojunction Devices: Heterojunctions Fundamentals, Heterojunction Field Effect Transistors (HEMTs), Heterojunction Bipolar Transistors (HBTs)
- Charge-Coupled Devices
- Memories
- MESFETs and JFETs
- Optoelectronic Devices: Photodiodes, Light Emitting Diodes, Lasers, and Solar Cells

533 Semiconductor Device/Process Simulation (Vasileska)

- Crystal lattices
- Electronic structure: empirical pseudopotential, tight-binding, k.p method
- Semiconductor transport: drift-diffusion and hydrodynamic models (velocity saturation vs. velocity overshoot)
- Basic properties, modeling, and transistor breakdown phenomena: MOSFETs, BJTs, HEMTs
- EEPROMs
- Basic properties of single junction and multijunction solar cells

534 Semiconductor Transport – PhD level class (talk to current instructor of this class)

535 Electron Transport in Nanostructures – PhD level class (talk to current instructor of this class)

536 Semiconductor Characterization (Thornton, Skromme, Yu Yao)

- Transfer length method (TLM) for measuring sheet resistance and contact resistance
- I-V characteristics and C-V profiling of p-n junction and Schottky diodes
- MOS capacitors and MOSFET parameter extraction (oxide charge density, V_{th} , g_m etc)
- Device failure analysis (electromigration, gate oxide breakdown)
- Reflection spectroscopy

537 Semiconductor Optoelectronics (Zhang)

- Introduction to optoelectronic materials
- Structural properties
- Electronic states and band structures
- Electrical properties
- Optical properties
- Application of the materials and structures in devices
- Light emitting diodes, Laser diodes, Photodetectors
- Photovoltaics and solar cells

539 Fundamentals of Solid-State Electronics (Goodnick)

- Semiconductor crystal structures
- Electronic structure of semiconductors
- Vibrational properties of semiconductors
- Intrinsic and extrinsic semiconductors and their statistics
- Generation recombination
- Electron scattering and transport

565 Solar Cells (King)

- Solar cell I-V curves
 - a. Ideal characteristics
 - b. Non-ideal effects
 - c. In circuits with multiple solar cells
 - d. Effects of optical concentration
- Quantum efficiency measurements
 - a. Calculation of solar cell current density based on quantum efficiency and incident spectra
 - b. Effects of carrier recombination in solar cell structures on quantum efficiency
- Equations relating carrier populations, recombination rates, quasi-Fermi level splitting, diode saturation current density
- Current transport equations for p-n junction solar cells based on drift, diffusion, carrier generation, carrier recombination

- Heterojunction solar cells
 - a. Effects on recombination
 - b. Heterojunction band diagrams
 - c. Heterojunction material systems
- Baseline structures and fabrication methods for the most common types of solar cells and modules

List of Solid-State Electronics Undergraduate Classes that can be taken as EEE591 Courses

434 Quantum Mechanics for Engineers (Goryll)

- Photon and electron energies and wavelengths
- Interpretation of the wave function and probabilities, operators
- Energy levels in potential wells (constant, linear, quadratic profile)
- Tunneling through barriers

435 Fundamentals of CMOS and MEMS (Thornton)

- Deal-Grove model for the thermal oxidation of silicon
- Ion implantation and diffusion of common dopants in semiconductors
- Modulation transfer function and minimum lithographic feature size
- Etching, selectivity, and anisotropy
- Process integration e.g. LOCOS isolation, self-aligned contacts, and sacrificial etching

436 Fundamentals of Solid-State Devices (Goodnick, Yu Yao, Wang)

- Metal semiconductor contacts
- MOS capacitors and MOSFETs
- Non-ideal effects and advanced MOSFETs
- Bipolar junction transistors
- Junction Field Effect transistors, MESFETs and HEMTs
- Optical processes, solar cell, optical detectors and emitters.
- High frequency and high power devices

437 Optoelectronics (Y.-H. Zhang, Ning)

- Wave nature of light
- Dielectric waveguides and optical fibers
- Semiconductor Science and light emitting diodes
- Stimulated emission devices: optical amplifiers and lasers
- Photodetectors and image sensing
- Solar cells

439 Semiconductor Facilities and Cleanroom Practices (Kozicki)

- Contamination and cost – basic economics, defects and yield.

- Counting particles and the natural distribution, cleanroom class and defect density.
- Particles in air – Brownian motion, falling particles, drag force and terminal velocity.
- Diffusion – Fick's first law and diffusivity, Fick's second law and its solutions.
- Bernoulli principle and lift force.
- Boundary layer.
- Van der Waals force, electrostatic attraction.
- Surface cleaning.
- Laminar flow.
- Airflow and particle count models.
- Filters in the airflow, recirculation and make-up air.
- Construction materials.
- Filter theory and operation.
- Temperature and relative humidity.
- HVAC systems.
- Refrigeration capacity, psychrometric charts.
- Vibration mitigation.
- Static sources, effects, models and control.
- Contamination in water, treatment, purification and standards.
- Ultrapure water production.
- People as contamination and cleanroom garments.
- Risk management, hazard categories, industrial hygiene, and toxicology.
- Materials in integrated circuit fabrication.
- Safety systems, organizations and regulations.
- Ultra-clean environments and robotics.

465 Photovoltaic Energy Conversion (Goryll, Honsberg, Meng Tao, King)

- The semiconductor diode: carrier lifetimes, dark current, short-circuit current and open circuit voltage under illumination, fill factor and efficiency
- Photovoltaic cell processing technology
- Photovoltaic modules: power output, shading
- Photovoltaic systems: power converter efficiency, battery sizing
- Economic analysis