General Information for Electrical Engineering (EE) PhD Qualifying Exam

(revised in August 2021)

The Electrical Engineering (EE) Qualifying Exam is administered in two parts: a written exam and an oral exam. The objective of the written exam is to determine the students' understanding of the fundamentals of EE subjects and to ensure solid theoretical background to start research. The objective of the oral exam is to evaluate the students' ability for critical thinking, problem-solving and communication required to conduct research independently. The oral exam will be administered only for the students who passed the written exam. Every PhD student is required to pass the Qualifying Exam, both written and oral exams, by the end of the second semester after completion of the M.S. degree or by the end of the fifth semester after completion of the B.S. degree.

Students who fail the Qualifying Exam on their first attempt will be given a second opportunity to pass the exam when it is given in the following semester. Students who fail the exam once and do not take the exam in the subsequent semester will no longer be considered PhD degree candidates in the ECE department. A student who fails the Qualifying Exam on two consecutive semesters may file a written petition with the ECE Graduate Studies Committee for a third attempt. The petition must include at least three faculty recommendations, documentation of academic and research progress, and documentation of extenuating circumstances. The committee will vote, by simple majority, to approve or deny the petition. If the petition is approved, it will be forwarded to the Office of Graduate Studies as a request to administer the last attempt.

- **Written exam (WE) Policy and Procedures**

Overall Procedure

The written exam will be normally held on the third weekend of each spring and fall semester. The written exam session is three hours long. Each student, when they register for the exam, will select four specialization areas for the written exam. Students will only be provided problems for the areas selected. Possible specialization areas that can be chosen include all emphasis areas of EE (Circuits/Electronics; Communications/Signal Processing; Control Systems; Waves/Devices; and Power/Machinery) and no more than one single emphasis area in computer engineering.

The written exam problems are selected to cover fundamental materials in EE. As a general rule, basic material from undergraduate and fundamental subjects from 5xxx-level courses will be covered. The problems are designed so that each problem should take approximately 15-20 minutes to work. The student is required to work eight of the sixteen problems (no more than three per area). The sixteen problems will consist of four problems from each of the four areas selected. Written exam subjects and associated study guides are available in a later section.

Reference Material

The Fundamentals of Engineering (FE) Reference Handbook (NCEES, version 9.2, 2013, http://www.engineering.uco.edu/~aabuabed/index_files/FE_Handbook.pdf) will be available to each student at the exam. Only several selected sections will be provided including: Units, Conversion Factors, Mathematics, Probability/Statistics. Note that this is intended to provide only the general information including fundamental formulae, constants and mathematical tables, etc. The authors of exam problems may not utilize this Reference Handbook when they design the problems. No other reference material is allowed. The only items students are allowed to bring to the exam are pencils, pens, erasers, and calculators (without network connectivity). Extra answer sheets will be provided by the exam proctor upon request. Extra calculator batteries or other supplies will not be available from the exam proctor. In order to keep track of the amount of time remaining during the exam, each student should bring his or her own watch.

Grading Policy

Each problem on the exams will be graded by the faculty member who wrote the problem. Generally, partial credit is given. A score based on the 4.0 - 0.0 scale including all intermediate scores, e.g. 3.6, 2.7, etc., (4.0, 3.0, 2.0 and 1.0 being equivalent to the letter grades "A", "B", "C" and "D", respectively), is given for each of the eight problems. The average score is determined by averaging the eight scores, respectively.

An average score of 3.0/4.0 is typically required for passing the written exam. Exam scores for each student will be reviewed by the ECE Graduate Studies Committee. The committee will determine if each student passes or fails the written exam. Students will be notified of the results of the exam, indicating "pass" or "fail", approximately one week after the exam is given.

A student may review the graded answers only in the presence of the graduate secretary, without taking pictures, making notes nor taking the answers with the student. If the student has any question on the solution of a particular problem, it should be done in writing in the presence of the graduate secretary within one week after the results are announced. The secretary forwards the writing and the student's answer sheet to the problem author without revealing the student's identity. The author provides the secretary with an anonymously written explanation to be forwarded to the student by the secretary. The faculty member may choose to meet the student instead of writing.

- **Oral exam (OE) Policy and Procedures**

Overall Procedure

Within five weeks of passing the written exam, the student's oral exam, an oral presentation (typically one hour, but no longer than two hours), must be scheduled. The advisor must form the student's tentative PhD graduate committee (at least three including the advisor) immediately after passing the written exam. Then, the student will notify the graduate secretary of the possible exam date/time after consulting with the committee members.

Two weeks (and no sooner) prior to the oral exam, the student will be given an assignment comprised of two journal articles relevant to the student's potential research topic, as agreed upon by the PhD committee. During the oral exam, the student will be required to

summarize and critique these articles. The student will be given no more than 15 minutes per article to give a complete overview of its technical contents. Subsequently within the next 30 minutes, the student will be required to properly place the novelty, shortcomings, how the student's future research fits within or builds upon the works in these articles, and other pertinent issues. Each examinee is required to prepare their oral presentation material. The required format for the presentation and the evaluation items are available in a later section.

The committee will be present during the oral exam to ask questions, discuss nuances and observe student's ability to engage in technical discussions, student's potential for performing independent research, etc. All committee members are required to physically attend the oral exam. Under unavoidable circumstance, the committee member may join the session remotely with permission from the Graduate Coordinator. At least half of committee members must be physically attending. The advisor should not speak on behalf of the student during the exam.

Assignment Handling

The PhD graduate committee will select two journal articles suggested by the student's advisor. Each article must be directly relevant to the potential research topic of the student and an original scholarly research paper (excluding review articles) conducted by third party researchers and published by professional societies and/or academic publishers with perceived authority (e.g. IEEE, Elsevier, etc.).

Two weeks before (and no sooner) the oral exam, the advisor must deliver the two selected articles to the student to be used for the oral exam. The committee (including the advisor) must not provide the student with any information related to this assignment nor discuss any technical issue directly related to the assignment during the entire period of exam administration.

Grading Policy

The PhD graduate committee will prepare a one-page Pass/Fail evaluation report before leaving the oral exam location. This report is comprised of an evaluation rubric and, if necessary, obligatory remedial action items that the student must meet to proceed to, or along with, planning the dissertation. An average score of 4.0 (in 5.0 – 1.0 scale), averaged from three rubric items available in a later section (Knowledge, Critical Thinking and Communication Skill) is typically required to pass the oral exam. The advisor is responsible for making sure that the required remedial actions are completed before the Comprehensive Exam is scheduled.

Students who fail the oral exam on their first attempt will be given a second opportunity during the following semester. It is at committees' discretion whether to use the same articles at the second attempt as during the first exam, or use different articles.

- **Study guides**

Written Exam (WE)

The following material, broken down by area, is intended to provide you with more information on the exam. Previous PhD Qualifying Exam problems are posted on the department web site.

Circuits/Electronics

The area covers basic concepts and problems in circuit theory and electronic circuits:

- theorems, such as superposition, reciprocity, Thevenin's, Norton's, maximum power transfer, and Tellegen's;
- methods for writing linearly independent equations for circuits, such as loop-current, node-voltage, and state equations;
- characterizations of a network, such as the two-port parameters (z, h, chain, etc.), the indefinite admittance matrix, and the scattering matrix;
- DC (operating point and/or transfer characteristics) and AC (magnitude and/or phase frequency response) steady-state and transient solutions of various circuits;
- circuits may contain R's, L's, C's, coupled coils, transmission lines, independent and controlled sources, bipolar transistors, JFET's, MOSFET's, nullors, NIC's, GIC's gyrators, etc.
- circuits may be in any of the standard configurations, such as amplifiers (difference, operational, etc.), or gates (TTL, ECL, etc.).
- Ideal Operational Amplifiers and nonideal effects in Operational Amplifier circuits.

Communications/Signal Processing

Problems will be selected from the following topics:

1. Linear System Theory. Topics may include, but are not limited to: Fourier series, Fourier transforms, Laplace transforms, linear time-invariant filter design and analysis. There is no single S&T course devoted to these topics, but they are covered in parts of EE 2120, 3320 and 3340.

2. Digital Signal Processing. Topics from EE 3410 and EE 5400 may include, but are not limited to: Analog-to-digital and digital-to-analog conversion, discrete time Fourier transforms, discrete Fourier transforms, Z transforms, discrete time linear time-invariant filter design and analysis. Note that these topics are also covered in EE 6400.

3. Probability and Stochastic Processes. Topics from EE 5440 may include, but are not limited to: Axiomatic definition of probability, pdf, CDF, moments, independence, orthogonality, correlation, Bayes theorem, total probability, stationary processes, random vectors, multi-dimensional pdf and CDF, wide sense stationary processes, power spectral density, correlation functions and matrices, Markov models. Note that these topics are also covered in EE 6410 and 6440.

4. Digital Communications. Topics from EE 3430, EE 3440 and EE 5420 may include, but are not limited to: Amplitude shift keying, frequency shift keying, phase shift keying,

frequency conversion, superhetrodyne receiver structures, coherent demodulation, non-coherent demodulation, signal space analysis, bit error rate calculation, noise analysis. Note that these topics are also covered in EE 6450.

Control Systems

The intent of the problems is examine the general background and understanding of classical and modern control system analysis and design techniques. Topics covered in a first course in classical control (EE 3320), a first course in digital control (EE 5300), and a lower-level graduate course in nonlinear control systems (EE 5325) should be reviewed. Note that these topics are also covered in the first few weeks of linear control systems (EE 6300). This information is provided to the student for general guidance. It should not be construed as representing an exhaustive set of exam topics.

Topics for a first course in classical control (EE 3320) would include, but are not limited to:

- System modeling
- Steady state errors
- Stability analysis
- Transient response analysis
- Controller/Compensator design
- General Linear System Theory.

Suitable review texts might include those by Phillips/Harbor, Dorf, Hostetter/Savant/Stefani, Franklin/Powell/Emami-Naeini, Kuo, or Ogata.

Topics for a first course in digital control (EE 5300) would include, but are not limited to:

- Representation of discrete-time systems, including state variable representations
- Transient response and error analysis of discrete-time systems
- Design of controllers and compensators using root locus and pole placement techniques
- Controllability and observability
- General Linear System Theory.

A suitable review text might include the Digital Control texts by Phillips/Nagel, Kuo, or Franklin/Powell.

Topics from a lower-level graduate course in nonlinear control systems (EE 5325) (or covered in the first part of EE 6320) would include, but are not limited to:

- Linearization of a nonlinear system
- Nonlinear system stability

A suitable review text would be the one by Jean-Jacques E. Slotine, Applied Nonlinear Control, Prentice-Hall, NJ, 1991.

Waves/Devices

This area includes electromagnetics and physical electronics. The morning session problems in this area are chosen from topics normally covered in EE3600 (Electromagnetic Fields and Waves), EE5630 (Wave Propagation and Transmission Lines), EE5640 (Antennas and

Propagation) and EE3250 (Electronic & Photonic Devices), as well as topics covered in any prerequisite courses.

Typical topics discussed in EE3600 include:

- Static electricity and magnetism
- Coulomb's law and Gauss's law
- Biot Savart law and Ampere's law
- Laplace's and Poisson's equations
- Energy, work, and potential
- Electric and magnetic properties of materials including boundary conditions, capacitance, resistance and inductance
- Electromagnetic waves
- Transmission lines.

Typical topics discussed in EE5630 include:

- Time-varying Maxwell’s equations
- Electromagnetic wave equation
- Reflection and transmission
- Wave polarization
- Bounce diagram
- Transmission line impedance equation
- Impedance matching principles
- Time-domain reflectometry

Typical topics discussed in EE5640 include:

- Antenna radiation pattern
- Antenna directivity, gain, effective aperture and efficiency
- Antenna polarization and Friis transmission formula
- Fundamentals of dipole, loops, helix antennas
- Antenna array fundamentals
- Principle of aperture and reflector antennas

Typical topics covered in EE3250 include:

- Fermi-Dirac statistics and energy band theory
- Electronic processes in materials
- P-n junction and diode theory
- MOS and field-effect transistors theory
- Bipolar junction transistors theory

- Optical processes in materials and photonic devices

Suggested review texts for relevant courses to these topics/areas are:

- Electromagnetics & Waves, 2nd Edition, by Inan, Inan and Said
- Fundamentals of Electromagnetics, 2nd Edition, by Cheng
- Engineering Electromagnetics, 8th Edition, by Hayt and Buck
- Antenna Theory, Analysis and Design, 4th Edition, by Balanis
- Antenna Theory and Design by Stutzman and Thiele (2012)
- Antennas for all Applications, 3rd Edition, by Kraus and Marhefka
- Semiconductor Devices, Physics and technology, 2nd Edition, by Sze
- Solid State Electronic Devices, 7th Edition, by Streetman and Banerjee
- Semiconductor Physics and Devices: Basic Principles, 4th Edition, by Neaman

Power/Machinery

This area will include one problem on the basics of electrical machines and transformers (basically EE3500 material). Subjects include:

- Basic magnetic circuits
- Transformers
- Energy Conversion
- Synchronous, induction, and brushless dc machines

This area will also include one problem on the basics of power system analysis, such as is taught in EE 3540. Subjects include:

- 3-phase ac circuit analysis, per unit representative
- Transmission line basics
- Transformer, generator, motors as system components
- Unbalanced systems and symmetrical components
- System representation and basic power flow analysis
- Fault analysis.

This area will also include problems from the following courses:

- Power Electronics - A study of power semiconductor devices applied to rectifiers, dc-dc converters, and dc-ac inverters. (EE5520)
- Power Systems (intermediate). A study of load flow methods, economic dispatch, fault analysis for balanced and unbalanced faults. (EE5540)

Computer Engineering

Students choosing a specialization area from computer engineering should see the guidelines for the computer engineering qualifying exam.

Oral Exam (OE)

All examinees are required to prepare their oral presentation material with respect to the following policy.

Presentation format (no more than 40 PowerPoint slides)

The suggested format for the presentation are as follows:

- Article#1 (no more than 10 slides for 15 min)
  - Motivation and rationale of article #1
  - Complete overview of the technical contents of article #1
- Article#2 (no more than 10 slides for 15 min)
  - Motivation and rationale of article #2
  - Complete overview of the technical contents of article #2
- Critique on article#1 (no more than 10 slides for 15 min)
  Critical analysis and discussion on:
  - Novelty
  - Shortcomings
  - Pertinent issues related with the examinees's own future research (e.g. how does the own research fit within article #1 and/or what common components does the own research share with article #1, etc.)
  - Pertinent issues related with the examinees's own future research (e.g. how article #1 can be improved and/or what advances can be made by the own research to build upon article #1, etc.)
  - Other pertinent issue if any
- Critique on article#2 (no more than 10 slides for 15 min)
  Critical analysis and discussion on:
  - Novelty
  - Shortcomings
  - Pertinent issues related with the examinees's own future research (e.g. how does the own research fit within article #2 and/or what common components does the own research share with article #2, etc.)
  - Pertinent issues related with the examinees's own future research (e.g. how article #2 can be improved and/or what advances can be made by the own research to build upon article #2, etc.)
  - Other pertinent issue if any

Evaluation rubric

The committee members will observe the students' ability required to conduct research independently. It will be evaluated based on the items in the rubric shown below. Therefore, the presentation material and the delivery of presentation should be prepared accordingly.

	Unsubstantiated (1)/ Developing (2)	**Marginal (3)**	**Acceptable (4)/ Proficient (5)**
Knowledge: an ability to apply	Does not reflect understanding of subject matter and	Reflects understanding of subject matter and associated literature	Reflects mastery of subject matter and associated literature

knowledge of subject matter within their field of study	associated literature		
	Demonstrates limited understanding of theoretical concepts	Demonstrates understanding of theoretical concepts	Demonstrates superior understanding of theoretical concepts
	Limited evidence of comprehension	Some evidence of comprehension	Significant evidence of comprehension
	Limited expansion upon previous research	Builds upon previous research	Greatly extends previous research
Critical Thinking: an ability to engage in productive critical thinking within their field of study	Demonstrates rudimentary problem-solving skills	Demonstrates average problem-solving skills	Demonstrates mature problem-solving skills
	Demonstrates limited originality	Demonstrates adequate originality	Demonstrates significant originality
	Displays limited creativity and insight	Displays creativity and insight	Displays significant creativity and insight
Communication: an ability to communicate effectively within their field of study	Presents reasonings incorrectly, incoherently or faulty	Presents reasonings coherently and clearly	Presents reasonings in a superior manner
	Defines objectives poorly	Defines objectives clearly	Defines objectives thoroughly
	Contains numerous grammatical and spelling errors	Contains some grammatical and spelling errors	Contains no grammatical or spelling errors
	Organization is poor	Organization is logical	Organization is excellent

- **Appendix**

List of written exam (WE) subjects: revised (effective Fall 2018) and previous tables

Revised subject list of EE PhD qualifying exam (effective in Fall 2018)

Power

1	EE 3500 Electromechanics
2	EE 3540 Power system design and analysis
3	EE 5520 Power electronics
4	EE 5540 Power systems engineering

2. Circuits/Electronics

5	EE 2100 Circuits I
6	EE 2120 Circuits II
7	EE 3100 Electronics I
8	EE 3120 Electronics II

3. Waves/Devices

9	EE 3600 Electricity and Magnetism (static)
10	EE 3600/EE 5630 Waves & transmission lines (time varying)
11	EE 5640 Antennas & Radiation
12	EE 3250 Electronic & Photonic Devices

4. Controls

13	General linear control systems theory from EE 3320/5300
14	State-space realization, state feedback control from EE 5300
15	Compensator design and system response from EE 3320/5300
16	System linearization and system stability from EE 5325

5. Communications

21	Linear system theory from EE2120/EE3320/EE3340
22	Digital signal processing from EE3410/EE5400
23	Digital communications from EE3430/EE3440/EE5420
24	EE5440 Probability and Stochastic Processes

Previous subject list of EE PhD qualifying exam

1. Power

M1	EE3500 Electromechanics
M2	EE3500 Electromechanics
M3	EE3540 Power system design and analysis
M4	EE3540 Power system design and analysis
A1	EE5520 Power electronics
A2	EE5540 Power systems engineering
A3	EE55xx/65xx Variable
A4	EE55xx/65xx Variable

2. Circuits/electronics

M5	EE2100 Circuits I
M6	EE2120 Circuits II
M7	EE3100 Electronics I
M8	EE3120 Electronics II
A5	EE5100 Advanced electronics
A6	EE5520 Power electronics
A7	EE5160 Computer-aided network design
A8	EE6150 Signal Integrity, High-Speed Digital & RF Design Lab

3. Waves/devices

M9	EE3600 Electromagnetics (static)
M10	EE3600 Electromagnetics (trans. lines)
M11	EE3250 Elect & photon devices
M12	EE3600 Electromagnetics (time varying)
A9	EE5640/5630 Antennas, propagation, trans lines

A10	EE6260 Integrated microsystems
A11	EE5600 Interference control
A12	EE6600 Advanced electromagnetics

4. Controls

M13	EE5300 Digital control (simple digital control)
M14	EE3320 Control systems (block diagram analysis)
M15	EE3320 Control systems (stability analysis)
M16	EE5300 Digital control (controllability)
A13	EE6300 Linear control systems (stability)
A14	EE3320 Control systems (compensator design)
A15	EE6300 Linear control systems (system response)
A16	EE5300 Digital control (state-space realization, state feedback controller)

5. Communication

M21	EE3420/3430 Linear systems and analog comm
M22	EE5400 Digital signal processing
M23	EE5420 Digital comm
M24	EE5440 Probability & Stochastic Processes
A21	EE3420/3430 Linear systems and analog comm
A22	EE6400 Digital signal processing
A23	EE6420 Digital comm
A24	EE6440/6450 Probability & Stochastic Processes