Ph.D. Written Preliminary Exam Purpose, Procedures, Policies and Format
(Revised June 2015)

- The purpose of Ph.D. preliminary exam is to determine if a student is well prepared for pursuing Ph.D. study in the Department of Electrical & Computer Engineering.

- The Ph.D. Written Preliminary Exam shall be administered by the ECE Graduate Committee Chair (GCC), or by his or her designee.

- Students must take the exam during the first two semesters (excluding Spring/Summer session) of doctoral study. Failure to take the exam within the first two semesters constitutes a failed attempt. Failure to take the exam in the third semester constitutes a failed 2nd attempt and will result in dismissal from the Ph.D. program unless the student appeals for the 3rd and final attempt. Student's appeal for the 3rd and final attempt must be supported by his/her advisor.

- The exam shall be administered every Fall and Winter semester. It shall be administered in the Fall semester on the third Friday of November and in the Winter semester on the Friday after the Spring Break.

- The exam formats for Fall-2015 and Winter-2016 are shown below. Each exam area will have two parts: closed book and open book parts. Each part of each area will be 1-hour long.

- **Fall-2015 Preliminary Exam**
  
  a) Electrical Engineering students shall choose three of the seven areas of specialization listed below.
  1. Communications
  2. Electromagnetic Fields and Waves
  3. Mathematics
  4. Network Theory and Electronic Circuits
  5. Photonics
  6. Solid State Electronics
  7. Systems and Control

  b) Computer Engineering students will be tested in the following two areas only.
  1. Computer Organization
  2. Data Structures and Algorithms

- **Winter-2016 Preliminary Exam**
  
  a) Electrical Engineering students will be tested on two areas. One area is Circuits, and it will be mandatory for all Electrical Engineering students. For the second area, the student will be selecting either Systems and Signals, or Devices
  1. Circuits
  2. a) Systems and Signals or b) Devices

  b) Computer Engineering students will be tested in the following two areas:
  1. Computer Organization
  2. Data Structures and Algorithms

- Faculty serving on subcommittees in each of the areas of specialization selected by students shall submit two one-hour sets of questions for the exam, one set for the morning session and one set for the afternoon session.
• There shall be a closed-book morning session from 9:30 a.m. to 12:30 pm that consists of three sets of questions for each EE student and two sets of questions for each CE students, one for each of the areas of specialization that were chosen by the student. Students will be given one hour time for each set of questions. The questions shall address fundamental concepts in the areas of specialization. No materials other than writing instruments and student I.D. card shall be permitted. The GCC will proctor the exam and provide paper and calculators.

• There shall be an open-book afternoon session of the exam from 2:30 p.m. to 5:30 p.m. that consists of three sets of questions for each EE student and two sets of questions for each CE students, one for each of the areas of specialization that were chosen by the student. Students will be given one hour time for each set of questions. The questions shall address advanced concepts in the areas of specialization. Students shall be permitted to bring reference books suggested by faculty. The reference books will be checked for inappropriate contents by GCC. No other materials than writing instruments and student I.D. card shall be permitted. The GCC will provide paper and calculators.

• The Faculty shall grade the exams and meet within two weeks to discuss the performance of the students on the exam. They will judge the performance of each student to be either pass or fail. The GCC shall inform each student in writing of the outcome of the exam. Only pass or fail grades in each area shall be reported to each student.

• Every student attempting the exam for the second time must be tested on the same areas of specialization that he/she failed.

• Each student must pass the Ph.D. Written preliminary exam in at most two attempts. A student who fails the first attempt must take the exam again the next semester. Failure to take the exam in the next semester constitutes a 2nd failure. As mentioned earlier, a student who fails the exam twice will be dismissed from the Ph.D. program unless the student appeals for the 3rd and final attempt. Student’s appeal for the 3rd and final attempt must be supported his/her advisor.

The Ph.D. Preliminary Topics

The knowledge level of the Ph.D. preliminary exam is at the ECE 4000 to 6000 course level. Below are listed the topics in the ten specialization areas of the Department of Electrical & Computer Engineering; the recommended courses and suggested references for providing a minimal background in the topics; and the faculty coordinators for each area of specialization. The coordinators are recommended by the ECE Graduate Committee and appointed by the chair of the department. The coordinators design and grade the exam, and make recommendations to the Graduate Committee regarding student performance.

(1) Communications (available only for Fall-2015 exam)

Coordinators: Y. Zhao (in charge), and John Liu

Applicants planning on taking this exam should expect to be tested on the following topics:

1. Fourier series and Fourier transform
2. Frequency response of linear systems
3. Discrete and continuous probability distributions and their characteristic functions
4. Stationary random processes
5. Auto correlation, cross correlation, and power spectral density
6. Convolution Theorem
7. Sampling Theorem
8. PCM, DM, DPCM
9. AM & FM
WSU courses recommended as providing a minimal background in the above topics are: ECE4700 and ECE5700.

Suggested reference:
S. Haykin, Communication Systems, latest Ed, John Wiley

(2) Computer Organization

Coordinators: Professors C. Xu, S. Mahmud, N. Sarhan (in charge), and S. Jiang

Applicants planning on taking this exam should expect to be tested on the following topics:

1. Instruction set architecture
2. Computer arithmetic and ALU
3. Processor design (data path and control unit)
4. Pipelining
5. Hierarchical memory systems
6. Storage systems
7. Input/output devices and interfaces
8. Basics of multiprocessor systems
9. Performance evaluation of computer systems

WSU courses recommended as providing a minimal background in the above topics are: ECE4680.

Suggested references:

(3) Data Structures and Algorithms

Coordinators: Professors C. Xu, S. Mahmud, N. Sarhan (in charge), S. Jiang and H. Singh

Applicants planning on taking this exam should expect to be tested on the following topics:

Topics:

1. Object-Oriented Design: encapsulation and information-hiding, separation of behavior and implementation, inheritance, operator overloading, templates, polymorphism, exceptions, UML class notation.
2. Principles of programming and software engineering.
3. Data abstraction using object-oriented programming techniques
4. Algorithms and problem-solving: problem-solving strategies, the role of algorithms in the problem-solving process, implementation strategies for algorithms, debugging strategies; the concept and properties of algorithms.
5. Basic searching and sorting algorithms.
   a. Sorting: selection, insertion, bubble, heap, radix, quick and merge sorting techniques.
   b. Searching: linear search, binary search and basic searching structures.
6. Recursion and recursive algorithms.
7. Implementation of the fundamental abstract data types using pointers, arrays and templates:
   a. Linear data structures, such as lists, stacks, queues, deques, and sets.
   b. Hierarchical data structures, such as binary trees and ordered oriented (or general) trees.
   c. Search structures, such as Hash tables, Binary search trees, Balanced trees, Priority queue implementations.
   d. Algorithms that make use of these data structures

8. Basic algorithmic analysis

This area covers the topics of ECE 4050, including Software Engineering principles.


(4) Electromagnetic Fields and Waves (available only for Fall-2015 exam)

Coordinators: I. Avrutsky (in charge), and Michael Wu

Applicants planning to take this exam should expect to be tested in the following major topics:

1. Electrostatics:
   (i) Static electric field and scalar potentials (Coulomb’s and Gauss’s laws)
   (ii) Electrostatic boundary conditions
   (iii) Electrostatic energy and forces
   (iv) Application (computation of fields, potentials, energy, capacitance. etc.)

2. Magnetostatics:
   (i) Static magnetic fields and vectorpotentials (Biot-Savart’s law)
   (ii) Boundary conditions
   (iii) Magnetic energy, forces, and torques
   (iv) Magnetic dipoles, magnetization, and magnetic circuits
   (v) Applications (computation of fields, energy, forces, inductance, etc.)

3. Steady Electric Currents:
   (i) Current density and Ohm’s law
   (ii) Electromotive force and Kirchhoff’s voltage law
   (iii) Equation of continuity and Kirchhoff’s current law
   (iv) Boundary conditions for current density
   (v) Applications (computations of currents, power dissipation, resistance, etc.)

4. Electrodynamics:
   (i) Time varying fields and Maxwell’s equations
   (ii) Electromagnetic wave boundary conditions
   (iii) Wave equations and their solutions
   (iv) Plane waves and propagation
   (v) Reflection and refraction of plane waves at a dielectric intrface
   (vi) Flow of electromagnetic power (Poynting vector)

Mathematical background in vector algebra, integral calculus, and differential equations is assumed.

The WSU course recommended as providing a minimal background in the above topics is ECE 4800.
References:

(5) Mathematics (available only for Fall-2015 exam)

Coordinators: Professors I. Avrutsky (in charge), John Liu, and H. Ying.

Applicants planning on taking this exam should expect to be tested on the following topics:

Calculus
1. limits and continuity
2. derivatives and partial derivatives
3. monotonicity
4. extremes of functions (one variable and multiple variables)
5. definite integral
6. indefinite integral
7. double and triple integrals
8. sequences and series
9. linear ordinary differential equations
10. applications (one variable and multiple variables)

WSU courses providing a minimal background in the above topics are: MAT 2010, MAT 2020, MAT 2030, and MAT 2150.

Suggested references:

(6) Network Theory and Electronic Circuits (available only for Fall-2015 exam)

Coordinators: M. H. Hassoun (in charge), R. Erlandson, M. Cheng, A. Basu, and Y. Xu

Students are allowed one textbook and a scientific calculator. No other material is permitted during the exam. No sample exam questions are provided.

Applicants planning on taking this exam should expect to be tested on the following topics:

1. Analysis of general linear passive/active circuits:
   (i) Formulation of network equations (nodal and mesh formulation)
   (ii) Time domain analysis (complete response, impulse response, etc)
   (iii) Sinusoidal steady state analysis (Phasor analysis)
   (iv) Fourier analysis
   (v) Frequency domain (s-domain) analysis: Laplace Transform analysis technique, transfer functions, complex-frequency plane, etc.
   (vi) Power computations

2. Passive Network Synthesis:
   (i) Tellegen’s Theorem and positive real functions (Hurwitz polynomials)
   (ii) Driving point synthesis (synthesis using partial fraction expansion)
(iii) Transfer function synthesis (unterminated and singly terminated ladder networks)

3. Basic Active Filter Synthesis:
   (i) Synthesis using inductance simulation
   (ii) Cascade realization
   (iii) Coefficient matching techniques

WSU courses recommended as providing a minimal background in the above topics are: ECE3300, ECE3330, ECE3570, ECE4330, and ECE5310.

Suggested references:

(7) Photonics (available only for Fall-2015 exam)

Coordinators: I. Avrutsky (in charge), and Y. Zhao

Applicants planning to take this exam should have a background in the following major topics:

1. Geometrical optics, Snell’s law, total internal reflection.
2. Wave propagation, diffraction, interference.
3. Optical waveguides, fiber and integrated optics.
4. Semiconductor light sources and detectors.
5. Optoelectronic devices for communication applications: couplers, filters, multiplexers/demultiplexers, switches, routers, wavelength converters, amplifiers.
6. Multiplexing technologies: WDM, TDM, CDMA

WSU courses recommended as providing a minimal background in photonics are ECE 4850 and ECE 5870. Electromagnetic fields and waves are also covered by ECE 4800.

Suggested references:

(8) Solid State Electronics (available only for Fall-2015 exam)

Coordinators: Professors A. Basu, M. Cheng, P-Y Chen, and X. Han (in charge)

Applicants planning on taking this exam should expect to be tested on the following topics:

1. Crystal Properties and Growth of Semiconductors
2. Atoms and Electronics
3. Energy Bands and Charge Carriers in Semiconductors
4. Excess Carriers in Semiconductors
5. Junctions
6. p-n Junction Diodes
7. Bipolar Junction Transistors
8. Field-Effect Transistors

WSU courses recommended as providing a minimal background in the above topics are: ECE4570 and ECE5550
Suggested reference:
B. G. Streetman, Solid State Electronic Devices, Prentice Hall, New Jersey

(9) Systems and Control *(available only for Fall-2015 exam)*

*Coordinators:* Professors F. Lin, L. Y. Wang, and H. Ying (in charge)

Applicants planning on taking this exam should expect to be tested on the following topics for both continuous-time and discrete-time systems:

1. System Representation
2. Control System Characteristics
3. Frequency Response
4. Closed-Loop Tracking and Disturbance Rejection
5. Root-Locus Techniques
6. Cascade and Feedback Compensation
7. Structural Properties of Linear Systems
8. State Variable and Output Feedback
9. Synthesis of Linear Regulators, Observers and Trackers
10. Parameter Sensitivity
11. Lyapunov’s Second Method
12. Optimal Control Using a Quadratic Performance Index

WSU courses recommended as providing a minimal background in the above topics are ECE4470, ECE5440, and ECE5470.

Suggested references:

(10) Circuits *(available from Winter-2016 exam)*

*Coordinators:* M. H. Hassoun (in charge), M. Cheng, A. Basu, and Y. Xu

This Exam covers materials that are typically taught in undergraduate linear circuit analysis courses and in the undergraduate electronic circuits course.

**Linear Circuits Topics**

- Analysis of linear resistive circuits (includes independent sources and ideal operational amplifiers).
- Solving for the complete response of linear circuits (first- and second-order) with energy storing elements, switches and various types of input signals including dc, sinusoids, exponential, and ramp. Such circuits may also include independent sources, ideal operational amplifiers and magnetic coupling.
- The analysis of a linear circuit hinges on the ability of generating the circuit equations (algebraic or differential). To this end, the student should be able to make decisions about the most efficient way to arrive at such equations by employing:
  - Nodal equations
  - Mesh equations
  - Hybrid nodal and mesh equations
  - Super nodes
  - Source transformations
Equivalent circuits
Kirchhoff's Laws
Thevenin and Norton theorems
Superposition theorem
Conservation of power theorem
Maximum power transfer theorem

- Operational Amplifier circuits: Identifying and designing inverting amplifiers, differential amplifiers, buffers, integrators and differentiators
- Transient analysis of first- and second-order circuit (time-domain analysis)
- AC steady-state analysis employing the phasor method
- Variable frequency circuits, electric filter classification, magnitude plots of $H(\omega)$
- Power calculations in steady-state circuits
- Magnetically coupled circuits
- Three-phase circuits


**Electronic Circuits Topics**

- PN junction diodes: Terminal characteristics; 0.7-V model; diode rectifiers.
- Bipolar junction transistors (BJTs): Physical structure and modes of operation; DC analysis; Small signal analysis (hybrid-$\pi$ model and T model); common-emitter amplifier, common-emitter amplifier with an emitter resistance; common-based amplifier; common-collector amplifier or emitter follower; basic current mirror circuit; basic concepts of amplifiers: input resistance, output resistance, open-circuit voltage gain.
- Metal-oxide-semiconductor field-effect transistors (MOSFETs): Physical structure and modes of operation; DC analysis; small signal analysis (hybrid-$\pi$ model and T model); common-source amplifier, common-source amplifier with a source resistance; common-gate amplifier; common-drain amplifier or source follower; basic current mirror circuit; basic concepts of amplifiers: input resistance, output resistance, open-circuit voltage gain;


(11) **Systems and Signals** *(available from Winter-2016 exam)*

**Coordinators:** M. H. Hassoun (in charge), Feng Lin, Le Yi Wang, Caisheng Wang, Hao Ying, John Liu

**Topics covered:**

**Basic mathematical tools**

- Algebra of real and complex numbers
- Trigonometric identities. Euler identity.
- Rational functions and their partial fraction expansion
- Linear algebra: Vector and matrix representation of systems of linear equations and their solution; Linear independence; Matrix determinant and inverse; Cramer’s rule; Gauss elimination
- Pre-calculus: Trigonometric, exponential, logarithmic (etc.) functions and their properties
Calculus: Integration and differentiation of analytic functions. Infinite series, infinite sums and convergence
Differential and difference equations: Solution of linear ordinary differential and difference equations

Signals
- Signal classification (continuous-time vs discrete-time, analog vs digital, causal vs non-causal, complex vs real, etc.)
- Signal transformations, decomposition and symmetry
- Computing signal average, energy and power
- Representation of the sum of sinusoids (with equal frequencies) in compact form
- Determining if the sum of sinusoidal signals is periodic and (if so) obtaining the fundamental frequency
- Power of a sum of sinusoids signal (with same and different frequency sinusoids)
- Power of a complex signal
- Parseval's Theorem applied to power calculation of periodic signals
- Convolution integral, its properties and its application to continuous and piece-wise signals
- Convolution of discrete-time signals

Special signals and their properties
- Unit-impulse function
- Unit-step function

Series representation of signals
- Fourier series representation of periodic signals (trigonometric, compact trigonometric and exponential series representation)
- Taylor series representation of non-periodic smooth signals and truncation error

Signal Transformations and their properties
- Laplace transform of causal signals
- Inverse Laplace transform of rational functions (utilizing the Laplace transform table)
- Fourier transform of a signal (causal and non-causal)
- Frequency content of a continuous-time signal
- Signal bandwidth
- Signal magnitude and angle spectra
- Inverse Fourier transform (utilizing Fourier transform table)
- Z-transform of causal discrete-time signals
- Inverse Z-transform of rational functions (utilizing Z-transform table)

Linear system analysis (given the linear time-invariant differential or difference equation)
- Classic solution for the complete response (natural plus forced) in the form $y(t) = y_n(t) + y_f(t)$ employing time-domain methods
- System solution for the complete response (zero-input plus zero-state) in the form $y(t) = y_{zi}(t) + y_{zs}(t)$ employing time-domain methods (including convolution)
- Time-domain solution of linear difference equations.
- Solution for the unit-impulse response, $h(t)$, and the unit-step response
• Application of the Laplace transform to solve a linear time-invariant differential equation to obtain $y(t) = y_{z1}(t) + y_{z2}(t)$
• Laplace transform method for determining the system’s transfer function $H(s)$, the unit-impulse response and the step-response
• Determining system’s stability based on the poles of $H(s)$
• Solving for the ac steady-state response of a linear system employing the Fourier transform
• Determining the steady-state response to a periodic signal by employing the Fourier series, Fourier transform and the superposition principle
• System solution for the complete response in the form $y[k] = y_{z1}[k] + y_{z2}[k]$ employing the Z-transform and its inverse
• Stability of linear discrete-time systems based on the poles of $H(z)$

Other applications of transform methods
• Design of basic closed-loop feedback systems in the Laplace domain ($s$-domain)
• Analysis of basic communication systems: Amplitude modulation and demodulation in the Fourier domain ($\omega$-domain)
• Derivation of the phasor method using the Fourier transform
• Signal bandwidth
• Properties of distortion-less transmission systems
• Basic electric filter design: Butterworth filters
• Synthesis of active circuits that implement a given transfer function $H(s)$ employing: Inverting amplifiers, differential amplifiers, buffers, and differentiators

Reference


The following chapters/sections (from the above reference textbook) can help the student prepare for the Systems and Signals Exam: Chapters 1, 2, 3, 4 (Sections: 4.1-4.7), 6 (Sections: 6.1-6.7), 7 (Sections: 7.1-7.5), 8, 9, 11 (Sections: 11.1-11.4).

(11) Solid State Devices (available from Winter-2016 exam)

Coordinators: I. Avrutsky, A. Basu, M. Cheng, P-Y Chen, X. Han (in charge), Y. Xu and Y. Zhao

Topics covered:

Crystal Properties and Growth of Semiconductors

Atoms and Electrons
**Energy Bands and Charge Carriers in Semiconductors**

**Excess Carriers in Semiconductors**

**Junctions**

**Field-Effect Transistors**

**Bipolar Junction Transistors**

**Optoelectronic Devices**

Students are expected to demonstrate proficiency in the topics outlined above.