MIDDLE EAST TECHNICAL UNIVERSITY

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

Ph. D. QUALIFYING EXAMINATIONS

GUIDEBOOK

March 2019
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FOREWORD

This guidebook is intended to provide information that the Ph. D. students of the Electrical and Electronics Engineering Department of METU need when they are preparing for the qualifying examinations.

The objective of the doctoral program is to motivate and prepare students such that they are able to a) carry out research independently, b) analyze scientific events with wide and deep perception and c) determine necessary steps to reach new synthesis and make contributions. Courses taken during doctoral education and the qualifying examination provide means of acquiring wide and deep knowledge in the related field, which is essential to grasp and enhance different aspects of science. Original contributions to the field are furthermore expected from the thesis work of the Ph. D. candidate.

In the following pages, the details of a Ph. D. qualifying examination procedure, which is consistent with the above objective, are given. In part I, the application procedures for the qualifying examination and the important points that the student should bear in mind, are provided. In part II, definitions of the various terms that are used in the description of the qualifying examinations are included. Also in this part, the specialization areas at the Department are identified and the contents of the topics contained in the background subjects, core subjects and special subjects are written in detail together with the related courses. This section should be studied carefully by the student before choosing the topics of the major and minor qualifying examinations and the student's supervisor's consent must be sought after consultations. The current rules and regulations governing the qualifying examinations are included in Part III.

We hope that students will find this guidebook useful.

The Committee for the Qualifying Examinations
HOW TO TAKE QUALIFYING EXAMINATIONS?

HOW TO APPLY?

1- Ph. D. qualifying examinations are held twice yearly, in May and in November.

2- A Ph. D. student must take his Ph. D. qualifying examinations in his fifth semester at the latest. Students who fail the qualifying examination are asked to take the examination again the following semester. Students failing the examination a second time are dismissed from the doctoral program.

3- Ph. D. Qualifying Examinations are conducted entirely in English.

4- Students who are going to take Ph. D. Qualifying Examinations must apply to the Department (Committee for the Ph. D. Qualifying Examinations) in April/October in written form indicating their major and minor specialization areas together with a special subject for the major examination. Their application form must be approved by their supervisors.

5- The times, dates and places of the written qualifying examinations and the names of the students whose applications are approved by the Committee for the Ph. D. Qualifying Examinations, will be announced in the beginning of May/November. The dates and times of the oral qualifying examinations which will follow the written examinations, will be declared by the coordinator of the concerned jury.

MAJOR AND MINOR EXAMINATIONS

A student is asked to take two separate examinations: 1) Major and 2) Minor Examinations.

1- Major Examinations are held in two parts: Written and oral. In these examinations students are responsible for the core and one of the special subjects of a specialization area.

2- Minor examinations are held in two parts: Written and Oral. In these examinations students are responsible for the core of a specialization area which must be different than the one chosen for major examinations.
The core and special subjects of different specialization areas together with the related courses are given in the second part of this guidebook.

As an example, a student who is going to take his major examination in “Telecommunications”, will be responsible for both the core and one of the special subjects of this specialization area, and for his minor examination he will be responsible only for the core of another specialization area, for example, the core of “Computer Engineering”.
PART II  DESCRIPTION OF
THE SPECIALIZATION AREAS

In Engineering, a “Doctorate of Philosophy (Ph.D.)” work contributes to the
advancement of science and technology by developing and implementing original
engineering concepts and solutions from the philosophy behind existing scientific and
technological knowledge.

The Ph. D. program at the Department of Electrical and Electronics
Engineering, METU, aims at conducting leading doctoral research in different areas
with potential impacts abroad and nationwide. These impacts are generally in the form
of copyrighted publications and/or patents together with international recognition.

It is understood that “qualifying examination” is an important milestone in the
course of a Ph. D. program. In order to achieve the main goals of a Ph. D. degree, a
student is expected to grasp not only the subject area he is going to specialize, but also
be equipped with at least one more area of the related disciplines of the department. In
this respect, a Ph. D. student is asked to take his minor examination in a different
specialization area other than his own, in which he is going to take his major
examination.

In what follows, a relevant and balanced Ph. D. qualifying examination
procedure, for Electrical and Electronics Engineering Department Ph. D. students, is
given. To establish such a procedure, the electrical and electronics engineering Ph. D.
education is analyzed and the vertically integrated courses are grouped as background,
specialization and special subjects. These terms are defined in the following sections
and the diagram below is given to clarify the grouping of courses mentioned in this
document.
DEFINITIONS:

A- Specialization Area

This term represents a major area of research and practice and is defined by a coherent set of subjects. The specialization areas are identified according to the existing research activities of the department. (These areas will be updated in the future when necessary).

Main specialization areas in the Department of Electrical and Electronics Engineering, METU, at present, are identified as follows:

1) Biomedical Engineering
2) Circuits and Systems
3) Computer Engineering
4) Control Systems
5) Electrical Machines and Power Electronics
6) Electromagnetics, Antennas and Microwaves
7) Electronics
8) Power Systems
9) Robotics
10) Signal Processing
11) Telecommunications

B- Core of a Specialization Area

Core defines the fundamentals and essence of a specialization area and is composed of subjects essential to do or follow research in all branches of that specialization area.

The core must contain at least two graduate courses.

C- Background Subjects

These are the subjects that form the basic knowledge for studying in a specialization area.

Background subjects are composed of

a) Undergraduate courses compulsory for all students of Electrical and Electronics Engineering,

b) Courses that do not belong to a specialization area but are nevertheless necessary to help in order to follow and understand fully the concepts in that particular area. These courses typically contain material common to several specialization areas.
D- Special Subjects

Special subjects are those areas of study which are specific or closely related to a specialization area having in depth coverage of the relevant subject.

E- Major Examination

This examination aims at evaluating the student's knowledge and analysis skills in the core subjects and in one of the special subjects suited to the intended research topic of the student.

The area of coverage is chosen so that the student has an in depth understanding of the field and also has the opportunity to do and follow research in overlapping branches of the specialization area. The coverage is limited to a manageable number of courses.

F- Minor Examination

This examination aims at evaluating the student's knowledge and limited analysis and synthesis skills in the core of a specialization area.

GENERAL

A Ph. D. student must take a major examination in a specialization area and a minor examination in the core of another specialization area. Each examination consists of separate written and oral sessions.

In the following pages background subjects, core subjects and special subjects of the presently existing specialization areas are described.
BIOMEDICAL ENGINEERING
Ph. D. QUALIFYING EXAMINATIONS

Background Subjects:

- **Signal processing**: Discrete-time signals and systems, sampling and reconstruction, linear time invariant systems, fast Fourier transform methods, Fourier analysis of signals using discrete Fourier transform, optimal filtering and linear prediction.

- **Linear System Theory**: Linear spaces, linear transformations, matrix algebra, differential equations. System concept: Dynamical system representation. Linear system time varying and time invariant representation.

*Related courses: EE 430, EE 501*

Core Subjects:

- **Modeling and instrumentation for physiological systems**: Electrical Sources and Fields, Introduction to Membrane Biophysics, Action Potentials, Volume Conductor Fields, Electrophysiology of the Heart, Electrocardiography (ECG), electric and magnetic lead fields, Electroencephalography (EEG), Magnetoencephalography (MEG), Electroneurogram (ENG), Electromyogram (EMG), Biopotential electrodes, Biopotential amplifiers, Patient safety, Grounding, Isolation, Shielding, Simple mechanical model of the cardiovascular system (CVS), Measurement of pressure and blood flow, The simple mechanical model of the ventilation, Measurement of respiratory volumes and flow, Models of O₂ and CO₂ transport in the respiratory and cardiovascular system, Models of neural regulation of respiratory system and CVS, Therapeutic and prosthetic devices.

- **Medical imaging**: Image reconstruction with nondiffracting sources in two dimensions, Image reconstruction with nondiffracting sources in three dimensions, Algebraic reconstruction algorithms, Ultrasonic Computed Tomography, Tomographic Imaging with Diffracting Sources, Ultrasonic Reflection Tomography, MRI methods, Flow and Flow-related MRI, Nuclear Tomographic Imaging, New Imaging Modalities.

*Related Courses: EE 416, EE 519, EE 515*

Special Subjects:

- **Digital Image Processing**: Two-dimensional (2D) signals; discrete Fourier analysis of 2-D signals, 2-D Z-transform and recursive systems, design and implementation of 2-D filters, image enhancement, image coding.

*Related Courses: EE 634*
• **Physiological Control Systems:** Definition of and examples of hemeostasis, body fluid compartments and compartmental analysis, models of the cardiovascular and respiratory systems, hormonal control mechanisms, neural control mechanisms, regulation of body fluid volumes and electrolytes, mathematical modeling, simulation and identification of physiological systems-, associated numerical methods.

*Related Courses: EE 518*

• **Numerical techniques in Electromagnetics:** Numerical solution of matrix equations and matrix eigenvalue problems, method of moments, finite difference and finite element methods, variational methods, spectral domain approach, the use of these methods in the solution of various antenna and scattering problems, and in the analysis of passive microwave component

*Related Courses: EE 522*
CIRCUITS AND SYSTEMS
Ph. D. QUALIFYING EXAMINATIONS

Background Subjects:

- **Basic Circuit Theory**: Lumped elements and circuits, resistive circuits, operational amplifiers, dynamic circuits, sinusoidal steady state analysis, complex frequency domain analysis, frequency response.

- **Basic System Theory**: Linear spaces and linear transformations, dynamical system representations, linearity, time-invariance, impulse response, system function, stability.

- **Basic Signal Theory**: Signal classification, convolution, correlation, Fourier series and transform, Laplace and z-transformations, sampling and reconstruction, random signals, stationarity, ergodicity, power spectral density, transmission of random signals through linear systems, introductory stochastic processes.

*Related Courses: EE 306/EE 531, EE 430, EE 501, EE 502.*

Core Subjects:

- **Circuit Theory**: Lumped elements and circuits, circuit topology, general circuit analysis, circuit theorems, passivity and stability. Characterizations of one-port and multiport RLCM circuits (positive real rational, bounded real rational and Foster functions and matrices), synthesis of one-port and two-port LC, RC and RL circuits, synthesis of one-port RLCM circuits.


- **Passive, Active and Digital Filters**: Approximation methods, lossless filters (synthesis of lossless two-ports between resistive terminations, frequency transformations), phase and loss equalizers, active RC filters, infinite impulse response and finite impulse response digital filters, finite precision numerical effects, switched capacitor filters.

*Related Courses: EE 507, EE 508, EE 601.*
Special Subjects:

- **High Frequency Filters and Matching Circuits:** Distributed circuits, distributed element filter design, design of singly and doubly terminated lossless matching circuits.
  
  *Related Course: EE 509*

- **Multiresolution Signal Analysis:** Fundamentals of signal decompositions, filter banks, wavelets, algorithms and complexity, subband coding.
  
  *Related Course: EE 505*
COMPUTER ENGINEERING
Ph. D. QUALIFYING EXAMINATIONS

Background Subjects:

- **Logic Design:** Number systems. Boolean algebra. Simplification of Boolean functions. Combinational logic. Synchronous and asynchronous sequential logic.


- **Principles of Computer Architecture:** CPU organization. Arithmetic logic unit

*Related Courses: EE 441, EE 445.*

Core Subjects:


- **Microprocessor:** Microprocessor architecture. Microprocessor programming. Peripheral organization. Memory unit. I/O interfacing. Interrupt processed I/O. Direct memory access. Microprocessor based communication.


*Related Courses: EE 442, EE 444, EE 445, EE 446, EE 447, EE 545, EE 546.*

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Special Subjects:

  *Related Course:* EE 542.

  *Related Course:* EE 543.

  *Related Course:* EE 548.

  *Related Course:* EE 586.
CONTROL SYSTEMS
Ph. D. QUALIFYING EXAMINATIONS

Background Subjects:

• **Linear System Theory:** Linear spaces, linear transformations, matrix algebra, differential equations. System concept: Dynamical system representation. Linear system time varying and time invariant representation.

• **Optimization:** Unconstrained nonlinear optimization: Steepest descent, Newton, conjugate gradient and Quasi-Newton type of algorithms. Constrained optimization algorithms. Fundamental theorems of linear optimization and the simplex algorithm.

*Related Courses: EE 501, EE 553.*

Core Subjects:

• **Linear System Analysis:** Dynamical system representations with emphasis to evaluation of system behavior: duality, controllability, observability and their relevant transform techniques.

• **Nonlinear Control Systems:** State space analysis methods: state trajectories and singularity analyses; analytic techniques of periodic phenomena: perturbation methods; equivalent linearization and oscillations in nonlinear feedback systems; stability and predictability of nonlinear systems.

• **Feedback Systems:** design of dynamic compensators; harmonic realization methods and oscillation control in linear and nonlinear feedback systems.

• **Discrete Time Control Systems:** time domain analysis; sampled data systems; stability; observer design; state space design methods, quantization effects.

*Related Courses: EE 302, EE 402, EE 404/EE 555, EE 502*

Special Subjects:

• **Intelligent Control:** Methodologies: Learning Control, Fuzzy Control, Neuro Control, Nonparametric Models of Uncertainty.

*Related Course: EE 559.*
• **Optimal Control**: Calculus of variations, optimality; Linear Quadratic Optimal Control Problems; Computational approaches.
  
  *Related Course: EE 554.*

• **Robotics**: Introduction to Robotics: mathematics of manipulators including treestructured and multiarms, inverse kinematics, dynamics, task and path planning. Robot hand gross motion control. Obstacle Avoidance. Hand fine motion control: contact analysis.
  
  *Related Course: EE 588.*

  
  *Related Course: EE 655.*

  
  *Related Courses: EE 407, EE 408.*

  
  *Related Courses: EE 557, EE 558.*

  *Additional Background: Stochastic processes*
Background Subjects:

- **Linear System Theory**: Linear spaces, linear transformations, matrix algebra, differential equations. System concept: Dynamical system representation. Linear system time varying and time invariant representation.

- **Electromechanical Energy Conversion**: Magnetic circuits, stored energy, losses, principles of electromechanical energy conversion. Singly and multiply fed electromechanical systems, DC machines. Rotating fields, induction and synchronous machines.

  *Related Courses: EE 501, EE 553, EE 361, EE 362*

Core Subjects:

- **Electromechanical Energy Conversion and Electrical Drives**: Sizing of electromechanical energy conversion devices, the relationship between losses and size. Performance calculation of electrical machines. Dynamic behavior of electrical machines. DC and AC motor speed control systems and their performance.

- **Power Electronics**: Power switches, protection of power semiconductors, thermal behavior, natural commutation, rectifiers, harmonics, power factor and utility factor for distorted waveforms. Forced commutation, inverters, inverter voltage control, choppers, parallel and series operation of static converters.


  *Related Courses: EE 463, EE 464, EE 462, EE 563, EE 561*

Special Subjects:


  *Related Course: EE 564*
• **Special Electrical Machines:** Stepping and switched reluctance motors and their characteristics. Drive circuits for such motors. Calculation of drive-system characteristics at variable speed operating conditions; acceleration, deceleration and control techniques.

  *Related Course: EE 568*

• **Advanced Power Electronics:** Design of forced commutation circuits for inverters and choppers. Switch mode power supplies, buck-boost circuits, unity power factor rectifiers, advanced inverter modulation techniques, inverters as reactive power generators and for harmonic elimination, resonant inverters, resonant DC link inverters, resonant AC link inverters. Cycloconverters, matrix converters.

  *Related Course: EE 569.*


  *Related Course: EE 565*
Background Subjects:

- **Telecommunications:** Analog transmission, modulation techniques, superheterodyne receivers, frequency division multiplexing, sampling process, digital transmission, noise.

- **Signal Processing:** Discrete-time signals and systems, sampling and reconstruction, linear time invariant systems, fast Fourier transform methods, Fourier analysis of signals using discrete Fourier transform, optimal filtering and linear prediction.

- **Linear Algebra:** Linear spaces, linear transformations, Hilbert spaces.

- **Mathematics:** Complex calculus, special functions, partial differential equations.

*Related Courses:* EE 435, EE 436, EE 430, EE 501, PHYS 503.

Core Subjects:

- **Electromagnetic Theory:** Fundamental concepts and theorems. Plane wave functions, cylindrical wave functions, spherical wave functions, wave transformations.

- **Antennas and Propagation:** Antenna parameters, linear antennas, antenna arrays, radiation from slot and aperture antennas, elements of ground wave, tropospheric and ionospheric propagation.

- **Microwaves:** Transmission lines, field and distributed circuit analysis, propagation in waveguiding structures, impedance transformation and broadband matching techniques. Matrix representation of microwave networks, generalized scattering parameters, active and nonlinear microwave systems, microwave equivalent circuits.

- **Numerical Methods:** Numerical solution of matrix equations and matrix eigenvalue problems, method of moments, finite difference and finite elements methods, variational methods, spectral domain approach.

*Related Courses:* EE 426, EE 427, EE 522, EE 523, EE 527.

Special Subjects:

- **Microwaves:** Microwave theory, applications and basic concepts of antenna theory: Scattering parameters, passive reciprocal and nonreciprocal devices, hybrids,
electromagnetic resonators, basic microwave filters and periodic structures. Synthesis of lumped and distributed element filters, equivalent circuits and circuit transformations for realization, filter design using prototypes. Field equivalence principles, surface wave antennas, microstrip antennas and arrays, broadband antennas, reflector antennas, horns.

Related Courses: EE 428, EE 509, EE 525, EE 528

- **Antennas and Propagation**: Wave propagation fundamentals, ground wave, tropospheric and ionospheric propagation, Antenna and environmental noise. Field equivalence principles, surface-wave and microstrip antennas, arrays, broadband antennas, reflector antennas, horn antennas. Induced current and aperture integration formulations, the Huygens-Fresnel principle, geometrical optics, plane wave spectrum representation, fast analysis of aperture type antennas, fast and slow wave structures, array analysis and synthesis techniques.

  Related Courses: EE 524, EE 525, EE 526.

  Additional Background: Optimization: Optimization algorithms such as steepest descent, Newton and Quasi-Newton, fundamental theorems of linear optimization and the simplex algorithm.

  Related Course: EE 553.

- **Radar Engineering**: Wave propagation fundamentals, ground wave, tropospheric and ionospheric propagation, Antenna and environmental noise. Induced current and aperture integration formulations, the Huygens-Fresnel principle, geometrical optics, plane wave spectrum representation, fast analysis of aperture type antennas, fast and slow wave structures, array analysis and synthesis techniques. Design principles and performance evaluation of pulsed radars, Statistical detection theory and radar cross-section of targets, CW, FM and Doppler radars. SAR and ISAR radars. Radar receiver design, high power microwave generation and amplification.

  Related Courses: EE 524, EE 526, EE 625, EE 626.

  Additional Background: Optimization: Optimization algorithms such as steepest descent, Newton and Quasi-Newton, fundamental theorems of linear optimization and the simplex algorithm.

  Related Course: EE 553.

- **Electromagnetic Field Theory**: Green's functions in rectangular, cylindrical and spherical coordinates, relation with the solution of EM related inhomogeneous partial differential equations, Watson transformation, the T-Matrix method, vector wave functions, dyadic Green's functions. Asymptotic series, asymptotic evaluation of integrals, Kirchoff and physical optics approximations, Luneberg-Kleine expansion, the eikonal and transport equations, geometrical optics, geometrical theory of diffraction, physical theory of diffraction, applications.

  Related Courses: EE 521, EE 624

- **Optics**: Ray optics, wave optics, beam optics, Fourier optics and photon optics electromagnetic theory of optics and polarization, optical waveguides, fiber optics, optical resonators, optical fiber sensors, optic systems. Application of Fourier theory to the analysis and synthesis of optical imaging and optical data processing systems. Propagation and diffraction of light. Fresnel and Fraunhofer approximations, image formation with coherent and incoherent light, optical data processing and holography.

  Related Courses: EE 627, EE 635.
Additional Background: Optical propagation in fibers, cables, connectors and couplers, principles of optical communication systems. Coherent and non-coherent optical fiber communication systems. Principles of lasers, quantum electronics, laser plasmas, laser optics, laser systems and applications. Optimization algorithms such as steepest descent, Newton and Quasi-Newton, fundamental theorems of linear optimization and the simplex algorithm.

Related Courses: EE 438/EE 512, EE 553, EE 614.
ELECTRONICS
Ph. D. QUALIFYING EXAMINATIONS

Background Subjects:

General electronics background including non-linear electronics.

- **Solid-State Electronics**: Basic semiconductor concepts, physics of p-n junction diodes, bipolar junction transistors, field effect transistors, biasing and small-signal models, secondary affects, and dynamic models.
- **Analog Electronics**: Amplifiers and frequency response, feedback in amplifiers, differential pair stages, current mirrors, operational amplifiers, and power amplifiers.
- **Digital Electronics**: Large signal transistor models, TTL, ECL, MOS, CMOS logic gates, and regenerative circuits.
- **Nonlinear Electronics**: amplitude modulation and analog multiplication, coupling networks, sinusoidal oscillators, frequency mixers, and converters.

Related Courses: EE 412, EE 414

Core Subjects:

- **Digital VLSI Design**: Design techniques for rapid implementations of very large-scale integrated (VLSI) circuits, MOS technology and logic, and design for testability.
- **Solid State Devices**: Quantum theory of solids, semiconductor fundamentals and carrier transport, p-n and metal-semiconductor junctions, BJTs and MOSFETs: principles, modeling and advanced issues, heterojunctions and advanced electron devices, optical properties of semiconductors, optical devices: photodetectors, solar cells, light emitting diodes and lasers.
- **Analog Integrated Circuits**: Power supply rejection and voltage references. Noise models and calculations with noise. Equivalent noise generators for bipolar and MOS transistors. Harmonic distortion and inter-modulation. Application of noise and distortion analysis to RF circuit components (low noise amplifiers, mixers and oscillators)
- **Analog VLSI Design**: NMOS and CMOS processes, transistor circuit modeling, current mirrors, operational amplifiers, pseudo analog techniques, continuous time and switched capacitor filters, A/D and D/A conversion, oscillator and phase locked loop design.

Related Courses: EE 413, EE 419, EE 510, EE 617
**Special Subjects:**

- **Solid-State Devices:** III-V compound semiconductor technology. Physics, fabrication, modeling, and integrated circuit applications of III-V compound semiconductor electron devices (MESFETs, MODFETs, and HBTs). Novel heterostructure electron devices. Optoelectronic integrated circuits  
  Related Course: EE 619  
  Related Course: EE 527

  Related Course: EE 610  
  Additional background: Microfabrication processes, characterization and testing methods in semiconductor technology.  
  Related Courses: Physics 411 or Physics 412 or Physics 527

  Related Course: EE 516

- **Infrared Devices and Systems:** Infrared radiation fundamentals, basics of thermal imaging, characteristics of infrared detectors, photon sensors and uncooled thermal detectors, characterization of infrared systems, industrial and other applications of thermal imaging.  
  Related Course: EE 514

- **Integrated Circuit Design:** MOS and CMOS circuits and processing technology, circuit characterization and performance estimation. CMOS circuit and logic design, structured design and testing. IC Design methodologies.  
  Related Course: EE 618

- **Semiconductor Device Modeling:** Energy band theory, Boltzmann Transport Equation and advanced carrier transport models including semi-classical nonstationary transport models, high field transport in semiconductors and properties of interest for device applications, advanced semiconductor device modeling and Monte Carlo technique for device simulation.  
  Related Course: EE 513
• **Beam Electronics**: Lens theory, electron motion, electronic space charge, analytical determination of electrostatic fields, general properties of electrostatic lenses, magnetic electron lenses, electron guns, design considerations for selected beam systems.

  *Related Course: EE 613*

  *Additional Background: Electromagnetic Wave Theory: Fundamental concepts and theorems, plane, cylindrical and spherical wave functions.*

  *Related Course: EE 523*

• **Optoelectronics**: Propagation of rays, spherical waves and Gaussian beams, optical resonators, modulation and detection of optical radiation, noise in optical detection and generation, interaction of light and sound. Lasers, fiber optics, and their applications.

  *Related Courses: EE 615, EE 627*

  *Additional Background: Lasers: Laser plasma, laser optics, principal lasers, laser systems and applications, and safety problems.*

  *Related Course: EE 614*


  *Related Courses: EE438, EE512*
Students who are accepted to the PhD program in 2018-2019 Fall term or later are subject to the ‘New Version’ given next. Students who started the program before 2018-2019 Fall term may choose any of the versions.

**Background Subjects:**

- **Computational Methods:** Numerical errors and their estimation, Approximation and interpolation, solutions of linear and nonlinear simultaneous equations, numerical differentiation and integration, introduction to statistical methods.

- **Optimization:** Unconstrained nonlinear optimization: Steepest descent, Newton, conjugate gradient and Quasi-Newton type of algorithms. Constrained optimization algorithms. Fundamental theorems of linear optimization and the simplex algorithm.

- **Linear System Theory:** Linear spaces, linear transformations, matrix algebra, differential equations. System concept: Dynamical system representation. Linear system time varying and time invariant representation.

*Related Courses: EE 443, EE 553, EE 501.*

**Core Subjects:**

- **Power System Analysis:** Structure of electrical power systems, Electrical characteristics of transmission lines, transformers and generators, representation of power system, symmetrical and unsymmetrical faults. Matrix analysis and solutions of power systems, load flow and short circuit analysis, transient stability analysis.

- **Wave Propagation:** Wave equations, modeling of aerial lines and cables, modal analysis of transmission lines, power line carrier communications, solution of transmission line transients using lattice, Fourier transform and time domain methods.

- **Economic Operation of Power Systems:** Modern power system operation, economic dispatch, transmission losses, linear and nonlinear programming techniques, hydrothermal coordination, power system security and rescheduling.

*Related Courses: EE 471, EE 472, EE 571, EE 579.*

**Special Subjects:**

- **High Voltage:** Field analysis, electrical breakdown in gases, breakdown in non-uniform field and corona, electrical breakdown of liquids and solids, erosion, insulating materials. Generation and measurement of high AC, DC, and impulse currents, testing transformers and series resonant circuits, sphere and uniform field
gaps, dielectric measurements. Principles of insulation coordination, lightning performance. Insulation principles in high voltage equipment, lightning discharges and over voltages, corona effects, electromagnetic interference generated by high voltage systems, insulators, circuit breakers, high voltage transformers and cables. High voltage measurement techniques, high voltage components, impulse current measurements, dielectric measurements, partial discharges.

Related Courses: EE 475, EE 476, EE 572, EE 575, EE 576.

- **Distribution and System Protection:** Fundamentals of distribution systems, forecasting methods, primary and secondary distribution, operational characteristics of cables, aerial lines and transformers, overcurrent and thermal protection, economics of distribution systems. Overcurrent protection, differential protection, motor protection. Distance protection, high speed protection, integrated protection.

Related Courses: EE 474, EE 478, EE 577.

- **Operation and Planning:** Power system planning concepts, generation system and transmission planning. Real time monitoring, principles of computer control systems, contingency and configuration analysis, detection, identification and correction of errors, real-time observability analysis. Modern power system operation and control techniques, unit commitment, interchange of power and energy, dynamic modeling of power systems, regulation, economic dispatch. Computational techniques, power system modeling, large sparse linear systems, vector and parallel processing.

Related Courses: EE 578, EE 574, EE 671, EE 674.

- **Power System Stability and Control:** Power system transient and dynamic stability, multimachine transient stability, speed governors and stabilizers. Modern power system operation and control techniques, dynamic modeling of power systems, regulation, economic dispatch. Computational techniques, power system modeling, large linear systems, vector and parallel processing.

Related Courses: EE 563, EE 573, EE 671, EE 674.
Students who are accepted to the PhD program in 2018-2019 Fall term or later are subject to the ‘New Version’ given here. Students who started the program before 2018-2019 Fall term may choose any of the versions.

**Background Subjects:**

- **Computational Methods:** Numerical errors and their estimation, approximation and interpolation, solutions of linear and nonlinear simultaneous equations, numerical differentiation and integration, introduction to statistical methods.

- **Optimization:** Unconstrained nonlinear optimization: Steepest descent, Newton, conjugate gradient and Quasi-Newton type of algorithms. Constrained optimization algorithms. Fundamental theorems of linear optimization and the simplex algorithm.

- **Linear System Theory:** Linear spaces, linear transformations, matrix algebra, differential equations. System concept: Dynamical system representation. Linear system time varying and time invariant representation.

*Related Courses: EE 443, EE 553, EE 501.*

**Core Subjects:**

- **Power System Analysis:** Structure of electrical power systems, electrical characteristics of transmission lines, transformers and generators, representation of power system, symmetrical and unsymmetrical faults. Matrix analysis and solutions of power systems, load flow and short circuit analysis, transient stability analysis.

- **Power System Real Time Monitoring and Control:** Power system real time monitoring and control problem, Power system computer control centers, Supervisory Data Acquisition and Control System (SCADA), System control strategies, Control levels. System security concept, Contingency analysis, Configuration analysis, State estimation, Decoupled state estimation methods, Detection, identification and correction of gross measurement errors, Real-time observability analysis.

- **Economic Operation of Power Systems:** Modern power system operation, economic dispatch, transmission losses, linear and nonlinear programming techniques, hydrothermal coordination, power system security and rescheduling.

*Related Courses: EE 471, EE 472, EE 574, EE 579.*
Special Subjects:

• **Operation and Planning:** Power system transient and dynamic stability, speed governors and stabilizers. Power system planning concepts, generation system and transmission planning. Computational techniques, power system modeling, large sparse linear systems, vector and parallel processing.
  
  *Related Courses: EE 573, EE 578, EE 674.*

• **High Voltage Techniques:** Field analysis, electrical breakdown in gases, breakdown in non-uniform field and corona, electrical breakdown of liquids and solids, erosion, insulating materials. Generation and measurement of high AC, DC, and impulse currents, testing transformers and series resonant circuits, sphere and uniform field gaps, dielectric measurements. Modeling of aerial lines and cables. Modal analysis of transmission lines. Principles of insulation coordination, lightning performance. Insulation principles in high voltage equipment, lightning discharges and over voltages, corona effects, electromagnetic interference generated by high voltage systems, insulators, circuit breakers, high voltage transformers and cables. High voltage measurement techniques, high voltage components, impulse current measurements, dielectric measurements, partial discharges.
  
  *Related Courses: EE 475, EE 476, EE 571, EE 575, EE 576.*
Students who are accepted to the PhD program in 2017-2018 Spring term or later are subject to the ‘New Version’ given next. Students who started the program before 2017-2018 Spring term may choose any of the versions.

**Background Subjects:**

- **Linear System Theory:** Linear spaces, linear transformations, matrix algebra, differential equations. System concept: Dynamical system representation. Linear time-varying and time-invariant representations.


*Related courses: EE 430, EE 447, EE 501.*

**Core Subjects:**


*Related courses: EE 587, EE 642, EE 584.*

**Special Subjects:**

Related courses: EE 543, EE 559, EE 586.

- **Robot Hands and Manipulation**: Grasp Jacobian and its use in grasp planning, contact analysis, compliant motion, collision-free wrist path planning, force closure/form closure, linear and nonlinear complementarity problems.  
  Related course: EE 588.

- **Machine Perception**: Bayes decision theory, parameter estimation and supervised learning, nonparametric techniques, linear discriminant functions, unsupervised learning and clustering, scene analysis, Lisp programming, description matching, goal reduction, natural constraints, solution paths, games, logic, theorem proving, knowledge representation, natural language understanding.  
  Related courses: EE 583/CENG 564, EE 586.
Students who are accepted to the PhD program in 2017-2018 Spring term or later are subject to the 'New Version' given here. Students who started the program before 2017-2018 Spring term may choose any of the versions.

**Background Subjects:**


- **Discrete-Time Control Systems:** Importance and advantages of discrete time system models in control. Time domain analysis of discrete-time systems. Sampled data systems. Stability; translation of analog design. State space design methods: observer theory, introduction to optimal design methods. Quantization effects. Laboratory work consisting of digital control of linear and nonlinear electromechanical systems; components of a digital control system; simulation models; Proportional-Derivative (PD) position control; lead-compensator speed control; pole-placement based state-space control of nonlinear cart-pendulum system; Optimal Linear Quadratic Regulator (LQR) based state-space control of flexible-joint and inverted pendulum systems; more advanced electromechanical control examples.

- **Analysis of Nonlinear Systems:** Dynamical system models, classification of equilibrium solution. Results on 2-dimensional systems; Poincare-Bendixon theory for limit cycles. Lyapunov theory; definitions of stability and applications to linear and nonlinear feedback systems. Input/output stability; definitions and derivation of frequency response criteria for stability.


*Related courses: EE430, EE402, EE406, {EE404 or EE555}, EE447*

**Core Subjects:**


• **Optimization:** Mathematical preliminaries on functions of several variables. Convexity and convex functions. Unconstrained minimization problems. Computational algorithms such as steepest descent, Newton and quasi-Newton methods. Constrained minimization problems and Kuhn-Tucker theory. Fundamental theorems of linear optimization and the simplex algorithm.


*Related courses: EE501, EE587, EE553, EE585 (old EE780).*

**Special Subjects:**

• **Robot Dynamics and Control:** System representation, stability, controllability, state feedback, state estimation, and realization. Uncertainty models and information representation: types of uncertainties and uncertainty measures. Intelligent control methodologies: learning control, fuzzy control, neuro-control.

*Related courses: EE502, EE559*

• **Vision and Learning:** Image Formation and Image Sensing, Binary Images and their Geometrical and Topological Properties, Region and Image Segmentation, Edge and Corner Detection, Photometric Stereo, Shape from Shading, Motion Field and Optical Flow, Photogrammetry and Stereo. Machine perception, Bayes decision theory. Parameter estimation and supervised learning; nonparametric techniques. Linear discriminant functions, unsupervised learning and clustering. Scene analysis, applications of pattern recognition.

*Related courses: EE583, EE584*


*Related courses: EE586, EE583*

*Related courses:* EE586, EE588
SIGNAL PROCESSING
Ph. D. QUALIFYING EXAMINATIONS
Old Version

Students who are accepted to the PhD program in 2019-2020 Fall term or later are subject to the ‘New Version’ given next. Students who started the program before 2019-2020 Fall term may choose any of the versions.

Background Subjects:


- **Linear System Theory**: Linear spaces, linear transformations, matrix algebra, differential equations. System concept: Dynamical system representation. Linear system time varying and time invariant representation.


**Related courses**: EE 430, EE 306/EE 531, EE 501, EE 553.

Core Subjects:

- **Discrete-time Random Signal Processing**: Discrete-time random signals, Linear transformations, Estimation and detection, Homomorphic processing, Optimal linear filtering, Linear Prediction.

- **Spectral Estimation**: Spectral estimation by linear prediction, MA, AR, ARMA modeling, EM method, MUSIC, ESPRIT algorithms.


**Related courses**: EE 503, EE 504, EE 603.
Special Subjects:

  
  Related course: EE 604.

  
  Related course: EE 634.

  
  Related course: EE 583.

  
  Related course: EE 633.

**Major Exam:**

Core, one of the special subjects, and the following:

**Multiresolution Signal Processing**: Multirate processing, Filter banks, Time and Frequency analysis: DCT, wavelets etc.

Related course: EE 505.

**Minor Exam:**

Core subjects.
SIGNAL PROCESSING
Ph. D. QUALIFYING EXAMINATIONS
New Version

Students who are accepted to the PhD program in 2019-2020 Fall term or later are subject to the ‘New Version’ given here. Students who started the program before 2019-2020 Fall term may choose any of the versions.

Background Subjects:


*Related courses: EE301, EE 306.*

Core Subjects:


*Related courses: EE 430, EE 503, EE 5506, EE 501.*
Special Subjects:

  *Related course: EE 504.*

  *Related course: EE 505.*

- **Spectral Estimation:** Spectral estimation by linear prediction, MA, AR, ARMA modeling, EM method, MUSIC, ESPRIT algorithms.  
  *Related course: EE 603.*

  *Related course: EE 604.*

  *Related course: EE 633.*

  *Related course: EE 634.*

  *Related course: EE 636.*

- **Pattern Recognition:** Machine perception. Parameter estimation and supervised learning; nonparametric techniques. Linear discriminant functions. Unsupervised learning and clustering. Scene analysis.  
  *Related course: EE 583.*

- **Vision:** Image Formation and Image Sensing, Calibration, Color, Radiometry and Photometric Stereo, Image Segmentation, Edge and Feature Extraction, Optical Flow and Tracking, Stereo and Structure from motion.
Related course: EE 584.

- **Radar Signal Processing:** Target models, clutter models, radar waveforms, ambiguity function, slow-fast time sampling, MTI techniques, clutter rejection, coherent-incoherent processing, detection, CFAR processing.

  Related course: EE 746.

- **Image Formation:** Multidimensional signals, transforms, and sampling. Propagation and diffraction of waves; optical imaging systems. Fourier transforms in antennas. The ambiguity function; radar imaging systems. Diffraction imaging systems. Reconstruction of images; linear and nonlinear inverse problems in imaging; ill-posedness and regularization. Statistical image reconstruction methods (likelihood and Bayesian methods); analytical and numerical optimization tools; iterative algorithms. Tomographic imaging with different types of tomography data.

  Related course: EE 798.

**Major Exam:**

Core and one of the special subjects.

**Minor Exam:**

Core subjects.
Background Subjects:


- **Linear System Theory**: Linear spaces, linear transformations, matrix algebra, differential equations. System concept: Dynamical system representation. Linear system time varying and time invariant representation.

- **Signal Processing**: Sampling and reconstruction. z-transform. Linear time invariant systems. Structures for discrete time systems. Filter design techniques. DFT and FFT. Fourier analysis of signals using DFT.

Related Courses: EE 306/EE 531, EE 430, EE 501.

Core Subjects:


- **Source Digitization**: Sampling theory. Quantizers. PCM, DPCM, DM etc.


- **Basic Information and Coding Theory**: Concepts of mutual information and entropy. Channel capacity. Source and channel coding theorems. Block and convolutional codes.

Related Courses: EE 435, EE 436, EE 535, EE 536, EE 533.
Special Subjects:

  
  *Related course: EE 637.*

  
  *Related course: EE 524.*

- **Coding Theory:** Arithmetic of Galois fields. Linear block codes: Cyclic codes-, BCH, RS etc. Convolutional codes. Efficient decoding algorithms for block and convolutional codes. Concatenation and interleaving of codes.
  
  *Related course: EE 534.*

  
  *Related course: EE 538.*

  **Additional Background:** Computer networks: ISO-OSI layered model. Medium access, data-link, network and transport layer protocols. Internet and internet tools.
  
  *Related course: EE 444/EE 542.*

  
  *Related course: EE 412/EE 511.*

  
  *Related courses: EE 427, EE 428.*
PART III    RULES AND REGULATION CONCERNING
THE Ph. D. QUALIFYING EXAMINATIONS IN METU

To reach the latest version of the rules and regulations concerning the Ph. D. Qualifying Examinations, visit:

METU Main Page

Academics

Academic Rules and Regulations

Academic Rules and Regulations Governing Graduate Studies

The doctoral comprehensive examination

ARTICLE 42 – (1) The doctoral comprehensive examination (DCE) is the assessment of the students’ knowledge of the basic subjects and concepts in their field, and of whether they possess the depth of scientific research related to doctoral work.

(2) In order to be eligible to take the DCE, students should successfully complete the courses and the seminar course, and their Cumulative Grade Point Average should be at least 3.00.

(3) A student may take the DCE twice the most.

(4) The DCE is administered twice a year, in May and November. The names of applicants for the DCE are submitted by the chair of the GSD to the concerned GS one month prior to the exam.

(5) Students in Ph.D. programs must take the DCE latest by the end of the fifth semester, and students in Ph.D. on Bachelor’s degree programs must take it latest by the end of the seventh semester.

(6) Comprehensive examinations are arranged and administered by a Doctoral Comprehensive Board of five faculty members from the concerned GSD who are assigned for a three-year term by recommendation of the chair of the GSD and approval of the concerned GSAB. The Board sets up examination juries in order to prepare exams in varied fields, and administer and evaluate these exams. An examination jury comprises five members, at least two of whom are from outside the University and one of whom is the student’s thesis supervisor. The supervisor has a right to vote. The DCE meetings may be open to instructors, graduate students and experts in the field. However, the audience is asked to leave the room during the decision phase.
(7) The DCE consists of written and oral examinations that will assess the students’ competence in the related field and their disposition towards research. The DCE is conducted in English in its entirety.

(8) Students who succeed in the written examination take an oral examination. The exam format and weight, success criteria and the calculation of the exam grades are determined by the Doctoral Comprehensive Board. The jury decides, by absolute majority, whether a student is to be deemed “successful” or “unsuccessful” by evaluating the results of the written and oral components of the exam. The concerned GS is notified of this decision latest within three days in an official report approved by Doctoral Comprehensive Board.

(9) The DCE jury may require a student who is successful in the DCE to take a course / courses additional to those taken even if the course load requirements have been fulfilled. Upon approval by the Doctoral Comprehensive Board, the concerned GS is notified of these courses through the concerned GSD chair. The student must earn the letter grade BB minimum in the specified courses. These courses are taken in NI status and are not counted in the Cumulative Grade Point Average. A student who cannot successfully complete these courses within the maximum period may not defend her/his thesis before a jury and is dismissed from the program.

(10) Students who fail their first exam re-sit the exam in the ensuing semester. If a student is deemed unsuccessful once again, then she/he is dismissed from the program.

(11) Students who fail to sit any phase of the DCE are considered to have exercised their right to take that exam and are deemed unsuccessful in that phase.

Doktora yeterlik sınavı

MADDE 42 – (1) DYS, öğrencinin alanındaki temel konular ve kavramlar ile doktora çalışmasıyla ilgili bilimsel araştırma derinliği ve sahip olup olmadığını ölçülmesidir.

(2) DYS’ye girebilmek için öğrencinin derslerini ve seminer dersini başarıyla tamamlaması ve genel not ortalamasının az 3,00 olması gerekir.

(3) Bir öğrenci en fazla iki kez yeterlik sınavına girebilir.

(4) DYS, mayıs ve kasım aylarında olmak üzere yılda iki kez yapılır. DYS’ye girmek için başvuran öğrencilerin adları sınavdan bir ay önce EABDB tarafından ilgili enstitüye bildirilir.

(5) Doktora programı öğrencileri en geç beşinci yarıyı, lisans sonrası doktora programı öğrencileri ise en geç yedinci yarıyı sonuna kadar yeterlik sınavına girmek zorundadır.

(6) DYS, EABDB tarafından önerilen ve ilgili enstitü yönetim kurulu tarafından onaylanan ve üç yıl süreyle atanan beş kişilik doktora yeterlik komitesi tarafından düzenlenir ve yürütülmektedir. Komite, farklı alanlardaki sınavları hazırlamak, uygulamak ve değerlendirme amacıyla sınav jürileri kurar. Sınav jürisi en az ikisi kendi

(7) DYS, öğrencinin ilgili bilim dalındaki yeteneğini ve araştırmaya olan eğilimini belirleyecek yazılı ve sözlü sınavlardan oluşur. DYS'nin tümü İngilizce olarak yapılır.


(9) DYS jürisi, DYS'yi başarıran bir öğrencinin, ders yükünü tamamlamış olsa bile en fazla iki ders almasını isteyebilir. İlgili Doktora Yeterlik Komitesi tarafından onaylanan bu dersler, ilgili EABD aracılığıyla ilgili enstitüye iletilir. Öğrenci, belirlenen derslerden en az BB notu almak zorundadır. Bu dersler NI statüsünde alınır ve genel not ortalamasına katılmaz. Bu dersleri azami sürenin sonunda başarı ile tamamlayamayan öğrencinin, tezini jüri önünde savunamaz ve programla ilisiği kesilir.

(10) DYS’de başarısız olan öğrencinin başarısız olduğu bölüm/bölümlerden bir sonraki yarıylıda tekrar sınavna alınır. Bu sınavda başarısız olan öğrencinin programla ilisiği kesilir.

(11) DYS’nin herhangi bir aşamasında sınav girmeyen öğrenciler bu hakkını kullanmış ve o aşamada başarısız olmuş sayılır.