(It will be applied from 2016-2017 Fall)

İZMİR INSTITUTE OF TECHNOLOGY
GRADUATE SCHOOL OF ENGINEERING AND SCIENCES
DEPARTMENT OF ELECTRICAL-ELECTRONICS ENGINEERING
CURRICULUM OF THE GRADUATE PROGRAMS

M.S. in Electronics and Communication Engineering

Common Core Courses:		Credit	ECTS
EE 500	M.S. Thesis	(0-1)	NC
EE 598	Research Seminar*	(0-2)	NC
EE 8XX	Special Studies	(8-0)	NC
EE 590	**Scientific Research Methods and Ethics for Engineers****	**(0-2)**	**NC**

*All M.S. students must register Research Seminar course until the beginning of their 4th semester.

**EE 590 Scientific Research Methods and Ethics for Enginners course should preferentially be taken within the first two semesters.

In addition, students enrolled in the program must take three of the following courses.

EE 502	Linear Systems Theory	(3-0)	3
EE 510	Photonics	(3-0)	3
EE 521	Advanced Electromagnetic Theory I	(3-0)	3
EE 531	Probability and Random Processes	(3-0)	3
EE 533	Digital Signal Processing	(3-0)	3
EE 550	Computational Biology	(3-0)	3
EE 551	Digital Communications I	(3-0)	3

Mathematical Foundations Course:

Student enrolled in the program must take one course from the Mathematical Foundations Course List. If EE 502 is taken as a core course, one additional course is required from that list.

Elective Courses:

The course work can be completed by taking the courses in the EE Course List or any engineering and science departments.

Total credit (min.) : 21
Number of courses with credit (min.) : 7

(It will be applied from 2016-2017 Fall)

Ph.D. in Electronics and Communication Engineering
Common Core Courses:

EE 598	Research Seminar*	(0-2) NC
EE 600	Ph.D. Thesis	(0-1) NC
EE 8XX	Special Studies	(8-0) NC
EE 590	**Scientific Research Methods and Ethics for Engineers****	**(0-2) NC**
EE 698	**Rersearch Seminar for PhD**	**(0-2) NC**

* Students that were accepted to the PhD program with a BS degree must take the EE 598 Research Seminar course.

**This course is not obligatory under the condition that it is taken during master studies. EE 590 Scientific Research Methods and Ethics for Enginners course should preferentially be taken within the first two semesters.

(It will be applied from 2016-2017 Fall)

Research Area Core Courses:

In addition to the common core courses, students enrolled in the program must choose a research area and take the research area core courses. For each core course or its equivalent taken in a previous study, one additional course is required. The research area courses for each area are given in the following lists.

Area 1: Intelligent Systems and Control

EE 502	Linear Systems Theory	(3-0) 3
EE 531	Probability and Random Processes	(3-0) 3
EE 532	Stochastic Analysis and Estimation for Dynamical Systems	(3-0) 3
EE 533	Digital Signal Processing	(3-0) 3
EE 534	Advanced Digital Signal Processing	(3-0) 3
EE 538	Detection and Estimation Theory	(3-0) 3
EE 543	Artificial Neural Systems	(3-0) 3
EE 546	Pattern Recognition	(3-0) 3
EE 547	Computer Vision	(3-0) 3
EE 556	Nonlinear Systems Analysis	(3-0) 3
EE 559	Nonlinear Control Design	(3-0) 3
EE 560	Robot Manipulator Control	(3-0) 3
EE 561	Advanced Robot Kinematics	(3-0) 3

EE 502 and EE 556 are the research area core courses in Area 1.

Area 2: Signal Processing

EE 531	Probability and Random Processes	(3-0) 3
EE 532	Stochastic Analysis and Estimation for Dynamical Systems	(3-0) 3
EE 533	Digital Signal Processing	(3-0) 3
EE 534	Advanced Digital Signal Processing	(3-0) 3
EE 535	Adaptive Filter Theory	(3-0) 3
EE 536	Speech Processing I	(3-0) 3
EE 537	Speech Processing II	(3-0) 3
EE 538	Detection and Estimation Theory	(3-0) 3
EE 539	Audio Signal Processing	(3-0) 3
EE 540	Wavelet Theory Multiresolution Signal Analysis	(3-0) 3
EE 541	Speech Synthesis	(3-0) 3
EE 542	Multidimensional Signal Processing	(3-0) 3
EE 545	Image Processing	(3-0) 3
EE 546	Pattern Recognition	(3-0) 3
EE 547	Computer Vision	(3-0) 3

(It will be applied from 2016-2017 Fall)

EE 548	Medical Imaging Systems and Applications	(3-0) 3
EE 549	Biomedical Image Analysis	(3-0) 3
EE 550	Computational Biology	(3-0) 3
EE 565	Biomedical Instrumentation	(3-0) 3

EE 531 and EE 533 are the research area core courses in Area 2.

<u>Area 3: Communication Systems</u>

EE 505	Communication Network Analysis	(3-0) 3
EE 531	Probability and Random Processes	(3-0) 3
EE 532	Stochastic Analysis and Estimation for Dynamical Systems	(3-0) 3
EE 533	Digital Signal Processing	(3-0) 3
EE 534	Advanced Digital Signal Processing	(3-0) 3
EE 535	Adaptive Filter Theory	(3-0) 3
EE 538	Detection and Estimation Theory	(3-0) 3
EE 544	Information Theory and Coding	(3-0) 3
EE 551	Digital Communications I	(3-0) 3
EE 552	Digital Communications II	(3-0) 3
EE 553	Error Control Coding	(3-0) 3
EE 554	Wireless Communications	(3-0) 3
EE 555	Computer Communication Networks	(3-0) 3
EE 557	Multiple Antenna Techniques in Wireless Communications	(3-0) 3
EE 558	Advanced Wireless Communication	(3-0) 3
EE 562	Telecommunication Circuits	(3-0) 3
EE 564	Bio-Inspired Multi-Scale Communications	(3-0) 3

EE 531 and EE 551 are the research area core courses in Area 3.

<u>Area 4: Electromagnetics, Microwave, Photonics and Optical Communications</u>

EE 510	Photonics	(3-0) 3
EE 511	Introduction to Optical Fiber Communications	(3-0) 3
EE 512	Advanced Optical Fiber Concepts	(3-0) 3
EE 513	Optical Fiber Sensors	(3-0) 3
EE 515	Optoelectronics	(3-0) 3
EE 516	Fourier Optics	(3-0) 3
EE 521	Advanced Electromagnetic Theory I	(3-0) 3
EE 522	Numerical Methods for Electromagnetics	(3-0) 3
EE 523	Antenna Theory	(3-0) 3
EE 524	Microwave Devices and Applications	(3-0) 3

(It will be applied from 2016-2017 Fall)

EE 525	Asymptotic Techniques in Electromagnetic	(3-0) 3
EE 526	Advanced Electromagnetic Theory II	(3-0) 3
EE 527	Microwave Measurement Techniques	(3-0) 3

EE 510 and EE 521 are the research area core courses in Area 4.

Out of Research Area Course:

Students enrolled in the program must take one course from any of the other research areas.

Mathematical Foundations Course:

Student enrolled in the program must take one course from the Mathematical Foundations Course List. If EE 502 is taken as a research area core course, one additional course is required from that list.

Elective Courses:

The course work can be completed by taking the courses in the EE Course List or any engineering and science departments.

Total credit (min.)	: 21 (for students with MS degree)
Number of courses with credit (min.)	: 7 (for students with MS degree)
Total credit (min.)	: 42 (for students with B.S. degree)
Number of courses with credit (min.)	: 14 (for students with B.S. degree)

Mathematical Foundations Course List:

EE 501	Principles of Mathematical Analysis	(3-0) 3
EE 502	Linear Systems Theory	(3-0) 3
EE 503	Mathematics for Operations Research and Optimization	(3-0) 3
EE 504	Matrix Computation	(3-0) 3
MATH515	Real Analysis	(3-0) 3
MATH516	Complex Analysis	(3-0) 3
MATH517	Advanced Linear Algebra	(3-0) 3
MATH518	Numerical Linear Algebra	(3-0) 3
MATH519	Methods of Mathematical Physics	(3-0) 3
MATH527	Basic Abstract Algebra	(3-0) 3
MATH533	Ordinary Differential Equations	(3-0) 3
MATH534	Partial Differential Equations	(3-0) 3
MATH539	Numerical Analysis	(3-0) 3
MATH540	Numerical Solution of Partial Differential Equations	(3-0) 3
PHYS501	Mathematical Methods of Physics I	(3-0) 3
PHYS502	Mathematical Methods of Physics II	(3-0) 3

EE Course List:

EE 501	Principles of Mathematical Analysis	(3-0) 3

(It will be applied from 2016-2017 Fall)

EE 502	Linear Systems Theory	(3-0) 3
EE 503	Mathematics for Operations Research and Optimization	(3-0) 3
EE 504	Matrix Computation	(3-0) 3
EE 505	Communication Network Analysis	(3-0) 3
EE 510	Photonics	(3-0) 3
EE 511	Introduction to Optical Fiber Communications	(3-0) 3
EE 512	Advanced Optical Fiber Concepts	(3-0) 3
EE 513	Optical Fiber Sensors	(3-0) 3
EE 515	Optoelectronics	(3-0) 3
EE 516	Fourier Optics	(3-0) 3
EE 521	Advanced Electromagnetic Theory I	(3-0) 3
EE 522	Numerical Methods for Electromagnetics	(3-0) 3
EE 523	Antenna Theory	(3-0) 3
EE 524	Microwave Devices and Applications	(3-0) 3
EE 525	Asymptotic Techniques in Electromagnetic	(3-0) 3
EE 526	Advanced Electromagnetic Theory II	(3-0) 3
EE 527	Microwave Measurement Techniques	(3-0) 3
EE 531	Probability and Random Processes	(3-0) 3
EE 532	Stochastic Analysis and Estimation for Dynamical Systems	(3-0) 3
EE 533	Digital Signal Processing	(3-0) 3
EE 534	Advanced Digital Signal Processing	(3-0) 3
EE 535	Adaptive Filter Theory	(3-0) 3
EE 536	Speech Processing I	(3-0) 3
EE 537	Speech Processing II	(3-0) 3
EE 538	Detection and Estimation Theory	(3-0) 3
EE 539	Audio Signal Processing	(3-0) 3
EE 540	Wavelet Theory Multiresolution Signal Analysis	(3-0) 3
EE 541	Speech synthesis	(3-0) 3
EE 542	Multidimensional Signal Processing	(3-0) 3
EE 543	Artificial Neural Systems	(3-0) 3
EE 544	Information Theory and Coding	(3-0) 3
EE 545	Image Processing	(3-0) 3
EE 546	Pattern Recognition	(3-0) 3
EE 547	Computer Vision	(3-0) 3
EE 548	Medical Imaging Systems and Applications	(3-0) 3
EE 549	Biomedical Image Analysis	(3-0) 3
EE 550	Computational Biology	(3-0) 3

(It will be applied from 2016-2017 Fall)

EE 551	Digital Communications I	(3-0) 3
EE 552	Digital Communications II	(3-0) 3
EE 553	Error Control Coding	(3-0) 3
EE 554	Wireless Communications	(3-0) 3
EE 555	Computer Communication Networks	(3-0) 3
EE 556	Nonlinear Systems Analysis	(3-0) 3
EE 557	Multiple Antenna Techniques in Wireless Communications	(3-0) 3
EE 558	Advanced Wireless Communication	(3-0) 3
EE 559	Nonlinear Control Design	(3-0) 3
EE 560	Robot Manipulator Control	(3-0) 3
EE 561	Advanced Robot Kinematics	(3-0) 3
EE 562	Telecommunication Circuits	(3-0) 3
EE 563	Special Topics in Electrical Engineering	(3-0) 3
EE 564	Bio-Inspired Multi-Scale Communications	(3-0) 3
EE 565	Biomedical Instrumentation	(3-0) 3
EE 571	Introduction to Microelectromechanical Systems (MEMS)	(3-0) 3
EE 572	Instrumentation in Nanoscience and Nanotechnology	(3-0) 3
EE 58X	Selected Topics in Electrical Engineering	(3-0) 3

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COURSE DESCRIPTIONS **Credit**

EE 500 M.S. Thesis (0-1) NC
Program of research leading to M.S. degree arranged between the student and a faculty member. Students register to this course in all semesters while the research program or write up of thesis is in progress. Student must start registering to this course no later than the second semester of his/her M.S. study.

EE 501 Principle of Mathematical Analysis (3-0) 3
Vector spaces, function spaces, linear transformations, convex and concave functions, metric spaces, convergent sequences, compactness; Differential calculus on R^n; Continuity and limits, sequences of functions, Gateaux and Frechet derivatives, Mean-value theorem, Taylor's theorem, inverse function theorem, implicit function theorem, manifolds; Integration: Riemann Integration, intervals, measure, integrals over R^n.

EE 502 Linear Systems Theory (3-0) 3
Linear spaces, normed linear spaces, metric spaces, Hilbert spaces. Matrix representation of Linear Transformations, change of basis. Fundamental theorem of differential equations. Dynamical systems. State transition matrix, impulse response matrix. Variational equation. Dynamic interpretation of eigenvalue-eigenvectors. Minimal polynomials, function of a matrix, bounded-input bounded-output stability, equilibrium points, stability in the sense of Liapunov. Algebraic equivalence, controllability, observability, minimal realization.

EE 503 Mathematics for Operations Research and Optimization (3-0) 3
Groups and fields, vector spaces, Linear transformations, Gauss-Jordan pivoting, Gram-Schmidt procedure, unitary space. Hyperplanes. Convex polyhedron, linear inequalities. Tucker's theorem for positive solutions. Minkowski's theorem. Eigenvector-eigenvalue problem. Definiteness. Jordan Canonical form theorem. Optimization theory on R^n: Constrained minimization problem, linear programming problem, Lagrange Multiplier Theorem, Kuhn-Tucker Conditions for Inequality constraints, convex programming.

EE 504 Matrix Computation (3-0) 3
Matrix multiplication problems, matrix analysis, general linear systems, special linear systems, orthogonalization and least squares, parallel matrix computations, the unsymmetric eigenvalue problem, the symmetric eigenvalue problem, lancoz methods, iterative methods for linear systems.

EE 505 Communication Network Analysis (3-0) 3
Introduction to queuing theory and queuing models: M/M/1, M/G/1, G/M/1. Networks of queues. Open and closed networks of queues. Packet switched and circuit switched network analysis. Multiple access communication analysis. Multi-class networks and flow control in communication networks.

EE 510 Photonics (3-0) 3
Photonics is a rapidly developing technology with applications in communications, medicine, computing, environmental studies, basic science, and many other fields. The course begins with the photon theory of light and an investigation of the interaction of light with matter emphasizing on polarization properties and statistical aspects. Based on this interaction, the processes of spontaneous emission, absorption, and stimulated emission are treated. This leads to the development of laser systems based on the resonator optics.

EE 511 Introduction to Optical Fiber Communications (3-0) 3
Optical propagation in fibers, attenuation, scattering, dispersion, polarization and non-linear phenomena in transmission. Optical sources and optical detectors. Coupling of sources and detectors to optical fibers, splicing and optical connectors. Non-coherent receivers and their performance, non-coherent optical fiber communication systems.

(It will be applied from 2016-2017 Fall)

EE 512 Advanced Optical Fiber Concepts (3-0) 3
Coherent optical fiber communication systems with heterodyne and homodyne demodulation. Optical fiber amplifiers, frequency division multiplexing and time division multiplexing. Wavelength Division multiplexing systems. Pulse propagation and compression. Solution.

EE 513 Optical Fiber Sensors (3-0) 3
Fiber optic sensor components: sources, photo detectors, couplers, connectors and splices; Light wave in fiber optic sensors. Interferometric fiber optic sensors, Phase modulated fiber optic sensors; Intensity modulated fiber optic sensors, Fiber optic sensor arrays and distributed sensing, Fiber optic telemetry systems.

EE 515 Optoelectronics (3-0) 3
Review of electromagnetic theory relevant to 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. Fiber optics applications.

EE 516 Fourier Optics (3-0) 3
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. Fourier transforming properties of lenses. Image formation with coherent and incoherent light. Transfer function of imaging systems. Optical data processing and holography.

EE 521 Advanced Electromagnetic Theory I (3-0) 3
Fundamental concepts and theorems. Plane, cylindrical and spherical waves. Plane waves in different medium. Vector and scalar potentials. Transmission lines, waveguides and resonant cavities. Radiating systems. Integral equation formulation of electromagnetic scattering. Periodic structures. Perturbation and variational techniques.

EE 522 Numerical Methods for Electromagnetics (3-0) 3
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 above methods in the solution of various antenna and scattering problems, and in the analysis of passive microwave components.

EE 523 Antenna Theory (3-0) 3
Fundamentals of electromagnetic radiation and antennas. The plane wave spectrum representation. Wire, slot horn, microstrip and reflector type antennas with emphasis on their applications in various frequency bands. Array analysis and synthesis techniques. Special types of antennas and polarizers.

EE 524 Microwave Devices and Applications (3-0) 3
Transmission lines and waveguides: line equations, coaxial line, waveguides, microstrip line; Passive devices: connectors, attenuators, resonators and filters, directional coupler, isolator and circulator; Microwave tubes: klystron, travelling-wave tube; Diodes: varactor diode, parametric amplifier, pin-diode, tunnel diode, Gunn devices, IMPATT; Transistors: bipolar and field effect, amplifiers, mixers, oscillators.

EE 525 Asymptotic Techniques in Electromagnetic (3-0) 3
Definition of asymptotic sequences, expansions and series. Laplace method for integrals; Watson's lemma. Method of stationary phase and method of steepest descent. Transform integrals and theirasymptotic evaluation. Singularities and asymptotic method of differential equations. Differential equations with a large parameter.

EE 526 Advanced Electromagnetic Theory II (3-0) 3
Green's functions, Advanced boundary value problems in cylindrical and spherical coordinates, special functions, integral equation formulations.

EE 527 Microwave Measurement Techniques (3-0) 3
Signal generators: classification, components and typical block diagramms, output spectra; Power measurement: measuring heads, measurement of modulated and pulsed signals, error sources; Frequency measurement: mechanical frequency- and wavelength-meters, electronical frequency counters; Spectrum

analyser: bandwidth, resolution, structure of spectrum analysers, measuring dynamic; Phase noise measurement: definition of phase noise, quantitative description, spectral power density, direct method, phase-detector method, frequency-demodulator-method, phase noise of pulsed signals; Network analyser: principle; components, error correction, calibration, scalar and vector analyser; Antenna measurement: characteristics of an antenna, measurement site, far-field condition, anechoic chamber, impedance, gain, radiation pattern; Automation of measurement systems: IEEE 488, bus system, interface functions, commands and programming languages.

EE 531 Probability and Random Processes (3-0) 3
Engineering applications of probability theory. Problems on events, independence, random variables and vectors, probability distribution and density functions, expectations, and characteristic functions. Dependence, correlation, and regression; multi-variate Gaussian distribution. Stochastic processes, stationarity, ergodicity, correlation functions, spectral densities, random inputs to linear systems; Gaussian and Poisson processes. Markov Chains and processes. Introduction to estimation theory and Wiener filtering.

EE 532 Stochastic Analysis and Estimation for Dynamical Systems (3-0) 3
Linear Algebra and linear systems review; Concepts in Estimation Theory: maximum likelihood (ML), maximum a-posteriori (MAP), least squares (LS), minimum mean square (MMSE) estimation; bias, variance, mean squared error, consistency, efficiency; Linear Estimation for Static Systems: LS estimation , polynomial fitting; Linear Dynamic Systems with Random inputs; State Estimation for linear dynamical systems: Kalman Filter; State Estimation in Non-linear Dynamical systems: extended Kalman filter, particle filtering, unscented Kalman filter; Stochastic differential equations

EE 533 Digital Signal Processing (3-0) 3
Sampling and quantization of continuous-time signals. Multirate processing of digital signals. Transform analysis of linear time-invariant systems: frequency response of rational system functions, stability and casuality. Digital filter design techniques: FIR and IIR filters. Effects of finite register length. Properties of windowing and short-time Fourier Transform analysis. Introduction to time-frequency representations. Computation of DFT, FFT techniques. DSP application project.

EE 534 Advanced Digital Signal Processing (3-0) 3
Parametric signal modeling, AR, ARMA, MA models. Non-parametric spectrum estimation. Optimum Linear Filters, Levinson-Durbin algorithm. Lattice filter structures. Least squares filtering and prediction. Parametric spectrum estimation. Fundamentals of adaptive signal processing. Introduction to Array Processing. Efficient Fourier transform and convolution algorithms. Short time Fourier Transform. Topics in digital filter design.

EE 535 Adaptive Filter Theory (3-0) 3
Study of the mathematical theory of various realizations of linear filters. Detailed study of linear optimum filtering, namely Wiener filtering, linear prediction, and Kalman filtering. FIR structures versus lattice filter structures. Method of least Squares, Comparative study of steepest descent, least-mean square (LMS) and recursive least squares (RLS) filter design algorithms.

EE 536 Speech Processing I (3-0) 3
Mathematical models of human speech production and perception mechanisms, speech analysis/synthesis techniques including linear prediction, filter bank models and homomorphic filtering. Applications to speech synthesis and automatic speech recognition.

EE 537 Speech Processing II (3-0) 3
Speech enhancement, feature extraction, the EM algorithm, acoustic modeling, language modeling, training algorithms, search algorithms, noise robustness, speaker adaptation, speaker recognition, and text to speech.

EE 538 Detection and Estimation Theory (3-0) 3
Classical statistical decision theory, decision criteria and composite hypothesis tests. Receiver operating characteristics and error probability, applications to radar and communications. Detection of signals with unknown and random parameters, detection of stochastic signals, nonparametric detection techniques.

Introduction to signal design, ambiguity function, the uncertanity principle. Applications to radar and sonar systems.

EE 539 Audio Signal Processing (3-0) 3
Characteristics of musical sounds. Temporal and spectral properties. Human auditory system and psychoacoustics. Audio signal analysis: automatic transcription, singing analysis, music information retrieval. Audio/speech coding: Linear prediction, ADPCM, and CELP algorithms for narrowband and wideband coding, mp3, midi representation. Audio/speech signal modification (time compression/expansion, pitch modification) and synthesis (model based, concatenative). Hardware: transducers: pick-ups, microphones, loudspeakers. Recording and processing devices: mixers, effects (pedals/multi-processors). Recording room acoustics. Musical instrument modeling: string instrument modeling, woodwind instrument modeling.

EE 540 Wavelet Theory Multiresolution Signal Analysis (3-0) 3
Tiime-frequency signal decomposition. Block transforms, subband filters, wavelet decomposition. Orthogonality, transform efficiency, coding gain performance. Wavelet transform: regularity, 2-channel filterbanks, wavelet families. DCT, lapped Orthogonal Transforms, other transforms. Parametric modeling of signal sources.

EE 541 Speech Synthesis (3-0) 3
Overview of text to speech synthesis methods. Formant synthesis, articulatory synthesis, concatenative synthesis. Architecture of data-driven methods for speech synthesis. Speech corpus construction: Unit coverage problem. Optimal text selection for recording. The greedy algorithm. Recording: Speaker selection, room acoustics and other practical problems. Segmentation: Automatic and semi-automatic methods. Unit selection algorithm: Defining the cost functions, viterbi search on a large corpus. Modeling and synthesis of prosody: Prosodic labeling, duration modeling, intonation modeling, synthesis of prosody from text. Signal processing methods for prosody modification, concatenation and smoothing out discontinuities: Harmonic model, linear predictive modeling, time-domain methods. Expressive/emotional speech synthesis: Dimensions of emotional speech, voice quality analysis/modification. Evaluation of speech synthesis systems. Speaker modification techniques for generation of new voices.

EE 542 Multidimensional Signal Processing (3-0) 3
Multidimensional functions and their Fourier transform. Multidimensional difference equations and their z-transforms. Two-dimensional FIR and IIR filter design methods. Stability and stabilization of 2-D system. Stochastic signal models and spectral estimation for multidimensional signals and systems.

EE 543 Artificial Neural Systems (3-0) 3
Biological neuron. McCulloch-Pitts neuron model. Feedforward network, feedback network, supervised and unsupervised learning: Hebbian learning rule, perceptron learning rule, delta learning rule. Single-layer perceptron classifier, linear machine and minimum distance classification; Multilayer feedforward networks, error back-propagation training. Single-layer feedback networks. Associative memories, cellular neural networks. Matching and self-organizing networks, character recognizing networks, linear programming modeling network, expert systems for medical diagnosis.

EE 544 Information Theory and Coding (3-0) 3
Information measures, characterization of information sources, coding for discrete sources. Discrete channel characterization, channel capacity, noise-channel coding theorems. Various error control coding and decoding techniques. Introduction to waveform channels and rate distortion theory.

EE 545 Image Processing (3-0) 3
Properties and analysis tools for multidimensional signal and systems. Image perception and human visual systems. Stochastic models for image representation. Transform techniques and image data compression. Analysis of video images, motion estimation. Image analysis and computer vision. Image reconstruction from projections.

(It will be applied from 2016-2017 Fall)

EE 546 Pattern Recognition (3-0) 3

Feature selection: Space transformations; Karhunen-Loeve expansion: Various distance measures. Supervised learning: Discriminant functions, linear and nonlinear training algorithms, statistical parametric and nonparametric methods. Nonsupervised learning: Clustering with known or unknown number of classes. Classification by neural networks.

EE 547 Computer Vision (3-0) 3

Properties of light. Human vision. Introduction to color image processing. Introduction to multi-sensor images, extraction of structural features from images, recognition methods for computer vision, image sequences, optical flow and motion.

EE 548 Medical Imaging Systems and Applications (3-0) 3

Medical imaging technology, systems, and modalities. Projection radiography: X-Ray systems, digital radiography. Computed tomography (CT): Principles, reconstruction methods, hardware. Magnetic resonance imaging (MRI): Mathematics, spin physics, NMR spectroscopy, fourier transforms, imaging principles. Ultrasound (US): Mathematical principles, echo equation, impulse response, diffraction, lateral and depth resolution, phased array systems, noise removal. Nuclear Medicine: Positron emission tomography (PET), single photon emission computed tomography (SPECT), imaging methods, resolution, 3-D imaging. Medical image storage, archiving and communication systems and formats: PACS, DICOM, TIFF. Image processing applications on medical images: Enhancement, segmentation, registration, compression, etc.

EE 549 Biomedical Image Analysis (3-0) 3

Bioimaging in histopathology. Digitized histologic slides: sectioning of tissue samples, immunohistochemical staining, image acquisition. Preprocessing of histology image data. Tissue segmentation. Region segmentation. Segmentation and morphological characterization of cell nuclei. Abnormality detection via pattern classification. Analysis of three-dimensional radiological sequences. Format conversion and preprocessing. Co-registration and lesion detection. Computational anatomy via deformable registration. Comparative group studies: statistical parametric mapping, high-dimensional pattern recognition. Computational anatomy in four dimensional sequences.

EE 550 Computational Biology (3-0) 3

This course will begin with a broad description of cellular organization in a molecular biology perspective including nucleic acid and protein structure. Computational methods for pattern detection and clustering will be introduced in the analysis of amino acid sequences of proteins. Probabilistic models of genetic evolution will be developed along with sequence alignment and motif detection algorithms. RNA and DNA analysis with microarrays will be discussed.

EE 551 Digital Communications I (3-0) 3

Elements of a digital communication system. Source coding. Channel capacity. Characterization ocommunication signals and systems. Optimum receivers for the additive Gaussian noise channel. Signal design for band-limited channels. Fading channels. Introduction to spread-spectrum communications.

EE 552 Digital Communications II (3-0) 3

Carrier and symbol synchronization. Block and convolutional channel coding. Introduction to multi-channel and multi-antenna techniques. Equalization.

EE 553 Error Control Coding (3-0) 3

Introduction to algebra and Galois fields. Various error control coding techniques including linear block codes, cyclic codes, BCH and Reed-Solomon codes, convolution codes. Viterbi algorithm. Trellis coded modulation.

EE 554 Wireless Communications (3-0) 3

Cellular radio design fundamentals: frequency reuse, handoff, interference and system capacity. Mobile channel characterization: large-scale path loss, log-normal shadowing ; small-scale fading and multipath, delay spread an coherence bandwidth, frequency selectivity, coherence time and Doppler spread, fast and slow fading. Modulation techniques for mobile radio; receiver complexity, error rate analysis, efficient spectral utilization. Different techniques of diversity and combining. Time, frequency and code division multiple access; packet reservation, space division multiple access. Capacity calculations and networking.

EE 555 Computer Communication Networks (3-0) 3
Introduction to the Internet, ethernet and wireless LANs. Principles of data communication, sections on transmission medium, important examples such as public switched telephone system, mobile phone system, cable television, ADSL, broadband wireless, DOCSIS. Fundamental principles of point-to-point protocols. Quality of service, integrated and differentiated services. ISO OSI networking layers. Transport control protocol, user datagram protocol, real time protocol, remote procedure call. Application and session layer protocols and examples.

EE 556 Nonlinear Systems Analysis (3-0) 3
Nonlinear differential equations, Induced norms and matrix measures. Second order systems. Linearization methods. Approximate analysis methods. Describing functions. Singular perturbations. Lyapunov stability, the Lur'e problem. Input-Output stability. Linear time-invariant feedback systems. Differential geometric methods. Frobenius Theorem. Reachability and observability. Feedback linearization. Stabilization of linearizable systems.

EE 557 Multiple Antenna Techniques in Wireless Communications (3-0) 3
Fundamental theories of multiple-input multiple-output (MIMO) which uses multiple antenna techniques in wireless communications systems. MIMO channel modelling and channel capacity. Spatial diversity techniques, the design of space-time codes and spatial multiplexing techniques. MIMO and space-time equalization and receiver structures. Exploiting feedback channel information in the transmitter using multiple antenna techniques. Orthogonal frequency division multiplexing (OFDM) with multiple transmit and/or receive antennas systems.

EE 558 Advanced Wireless Communications (3-0) 3
Introduction to wireless systems and communication channels. Fundamentals of adaptive modulation techniques. Informatics theoretical perspective of multiuser systems. Feedback channel issues. Spectrum sensing and sharing algorithms for cognitive systems. Broadband wireless systems. Fundamentals of Wimax standard.

EE 559 Nonlinear Control Design (3-0) 3
This course provides the advantages of nonlinear control over linear control. The Lyapunov stability techniques will be presented for control of nonlinear systems. The course will cover various nonlinear control techniques such as adaptive, robust, sliding mode, learning, passivity-based, and filter-based control.

EE 560 Robot Manipulator Control (3-0) 3
This course provides an overview of robot mechanisms, kinematics, dynamics, and focuses on advanced control techniques for robots. Topics include the derivation of robot kinematic and dynamic models, introduction to control theory, and computed-torque, robust, adaptive and neural network control techniques for robots.

EE 561 Advanced Robot Kinematics (3-0) 3
This course provides a detailed analysis of robot kinematics and focuses on kinematically redundant robot manipulators. Topics include forward and inverse robot kinematics, kinematic singularities, kinematically redundant and hyper-redundant robot manipulators, analysis of kinematic redundancy, motion in the null-space of the manipulator Jacobian, control of the null-space motion, and various sub-control objectives.

EE 562 Telecommunication Circuits (3-0) 3
Small and large signal high frequency amplifier design. High frequency oscillators. Noise considerations in Radio Frequency (RF) amplifiers. RF amplifiers. Phased-Locked Loops. Modulators and Demodulators.

EE 563 Special Topics in Electrical Engineering (3-0) 3
Course content is selected by the instructor from current research topics.

(It will be applied from 2016-2017 Fall)

EE 564 Bio-Inspired Multi-Scale Communications (3-0) 3
Diffusion and Reaction Diffusion Equations, First-passage and Occupation Probabilities, Accuracy of Concentration and Gradient Sensing, Molecular Modulation/Demodulation, Information Theoretical Approaches to MC, Detection and Estimation of Molecular Information, Ant-Colony Algorithm, Artificial Immune System Algorithm, Foraging Theory, Ant Colony-Inspired Routing Algorithm for Ad Hoc Networks, Immune System-Inspired Opportunistic Spectrum Access in Cognitive Radio Networks, Foraging Theory-Inspired Cross-Layer Communication in Wireless Sensor and Actor Networks.

EE 565 Biomedical Instrumentation (3-0) 3
Principles of instrumentation and applications related to biomedical sensor technologies and their integration with electronic interfaces will be introduced. Electronic instrumentation for biomedical signal conditioning and processing and electrical safety requirements in clinical settings will be covered. The properties of a variety of sensor materials, sensor configurations and their applications in observation of biomedical signals will be studied.

EE 571 Introduction to Microelectromechanical Systems (MEMS) (3-0) 3
Micotransducers and their application areas will be discussed. The steps in designing a microtransducer will be presented. Basic engineering mechanics concepts will be presented. The modeling and simulation using finite element analysis software will be demonstrated. Bulk and surface micromachining techniques will be introduced. Electronic circuitry, basic feedback topologies, and the noise in the microelectromechanical systems will be analyzed.

EE 572 Instrumentation in Nanoscience and Nanotechnology (3-0) 3
Nanomaterials, nanostructures, nanosensors, and their application areas will be discussed. Recent research on building nanoscale electronic circuits will be presented. Basic concepts in nanobiotechnology will be presented. The components of a scanning probe microscope will be analyzed and its operation principle will be explained. Measurement, characterization, and manipulation at the nanoscale will be discussed.

EE 58X Selected Topics in Electrical Engineering (3-0) 3
Course content is selected by the instructor from current research topics.

EE 598 Research Seminar (0-2) NC
A seminar must be given by each student an his research area which is graded by academic member of staff. The topic of the seminar can be decided by the student and his supervizor

EE 600 Ph. D. Thesis (0-1)NC
Original research work done by the student under supervision of and an advisor written in the graduate thesis format.

EE 8XX Special Studies (8-0) NC
Graduate students supervised by the same faculty member study advanced topics under the guidance of their advisor.

EE698 Research Seminar For PhD. (0-2) NC
This course aims at improving the student’s skills in literature search, data collection, reporting the results, and giving technical presentation. The student will attend the thesis proposal seminars at the department and the Institute. Finally, the student will give a seminar on a subject related to his/her research area.

EE 590 Scientific Research Methods And Ethics For Engineers (0-2)NC
This course will investigate the application of the scientific method to the scientific research practice in electrical and electronics engineering and the ethical concepts applicable to the publication practice during and after these research processes. After the scientific method is presented to the students along with its applications in various disciplines, the methods followed in the scientific research projects within the specific field of electrical and electronics engineering will be explained within a framework of matters pertaining to project proposal preparation, submission of progress and final reports and publication of the obtained findings.

(It will be applied from 2016-2017 Fall)

Afterwards, science, publication and engineering ethics concepts including privacy of personal information, efficient use of resources and plagiarism in relation to both processes of conducting scientific research and publication of findings will be introduced.

MATH 515 Real Analysis (3-0) 3

Lebesgue measure and Lebesgue integration. The Lebesgue spaces. General measure and integration. Decomposition of measures. Radon-Nikodym theorem. Extension of measures. Product measures and Fubini's theorem.

MATH 516 Complex Analysis (3-0) 3

Analytic functions. Cauchy-Riemann equations. Harmonic functions. Elementary functions: the exponential function, trigonometric functions, hyperbolic functions. The logarithmic function and its branches. Contour Integrals and Cauchy’s theorem. Cauchy integral formula. Liouville’s theorem and the fundamental theorem of algebra. Maximum moduli of functions. Incompressible and irrotational flow. Complex potential. Laurent’s series and classification of singularities. Sources and vortices as singular points of potential flow. Calculus of residues. Conformal mappings. Fractional linear transformations. Applications of conformal mappings.

Laplace’s equation. Electrostatic potential. Elements of elliptic functions. Analytic continuation and elementary Riemann surfaces.

MATH 517 Advanced Linear Algebra (3-0) 3

Vector spaces, matrices, linear mapping, scalar products and orthogonality, determinants, symmetric, hermition and unitary operators, eigenvectors and eigenvalues, polynomials and matrices, primary decomposition and jordan normal form.

MATH 518 Numerical Linear Algebra (3-0) 3

Solution of linear equations, eigenvector and eigenvalue calculation, matrix error analysis, reduction by orthogonal transformation, iterative methods.

MATH 519 Methods of Mathematical Physics (3-0) 3

Vector and tensor analysis. Potential theory and Dirac delta function matrices and groups. Continuous groups , distributions, Hilbert spaces. Differential equations, nonhomogeneous equations. The special functions I. The special functions II. Fourier series and integral transform. Laplace, Mellin and Hankel transforms .Calculus of variations. Integral equations.

MATH 527 Basic Abstract Algebra (3-0) 3

Integers. Sets. Linear Algebra. Groups. Subgroups. Factor groups. Isomorphism theorems. Finitely generated Abelian groups. Rings. Ideals. Maximal, prime ideals. PID. Irreducible polynomials. Fields. Algebraic extensions. Modules. Exact sequences.

MATH 533 Ordinary Differential Equations (3-0) 3

This course develops techniques for solving ordinary differential equations. Topics covered include: introduction to First-Order Linear Differential Equations; Second-Order Differential Equations, existence and uniqueness theory for first order equations, power series solutions, nonlinear systems of equations and stability theory, perturbation methods, asymptotic analysis, confluent hyper geometric functions. Mathieu functions. Hill's equation.

MATH 534 Partial Differential Equations (3-0) 3

General theory of partial differential equations; first order equations; classification of second order equations; theory and methods of solution of elliptic, parabolic, and hyperbolic types of equations; maximum principles; Green's functions; potential theory; and miscellaneous special topics.

(It will be applied from 2016-2017 Fall)

MATH 539 Numerical Analysis (3-0) 3

Error analysis, direct and iterative methods for linear systems of equations, solution of nonlinear equations, and systems of nonlinear equations. Interpolation and approximation theory, numerical differentiation and integration.

MATH 540 Numerical Solution of Partial Differential Equations (3-0) 3

Finite difference schemes for parabolic, hyperbolic, elliptic equations. Order of the Accurancy of finite difference schemes. Stability of and convergence for difference schemes. Leapfrog, Lax-Wendroff, implicit, ADI methods, SOR, direct methods for partial differential equations

PHYS 501 Mathematical Methods of Physics I (3-0) 3

Mathematical techniques as applied to the equations of theoretical physics. Linear vector spaces. Calculus of variations. Sturm-Lioville problem.

PHYS 502 Mathematical Methods of Physics II (3-0) 3

Green’s function. Integral transforms. Integral equations