Introduction

The Preliminary Exam is given each Fall (on the Monday of the Fall Semester mid-term break) and Spring semester (on the first Saturday of March). Students intending to take the exam must submit a registration form to the ECE Graduate Affairs Office by the deadline indicated on the form. The registration form is available on the ECE website. Registration for the prelim exam is open to all ECE graduate students. ECE undergraduate students with GPA of 3.5 or higher may also register for the exam. Students admitted with the PhD classification and MS students intending to pursue the PhD degree should take the exam at the earliest opportunity.

PhD and MS students can take the exam a maximum of three times within their first four semesters (not counting summer sessions) in the program. Students admitted into the graduate program as MS students must pass the prelim exam to be readmitted as PhD students.

The Preliminary Examination is administered in a double-blind fashion. Students taking the exam are issued code numbers by the ECE Graduate Affairs Office. Each student records their code number on the materials submitted for grading, no name is recorded on the exam materials. A score of 65% is needed in order to pass the exam.

The Preliminary Exam consists of 22 problems taken from core, breadth and undergraduate elective courses. From the 22 problems of the overall examination, each student must select eight to work and submit for grading. Students are given 4 hours to work the exam problems. The exam topics are listed in the ECE Preliminary Examination Study Guide, with courses in parenthesis that represent the scope of the material to be covered on the exam.
Preliminary Exam Content

There will be a total of 22 questions distributed as follows:

- CSS provides 2 problems from the material covered in ECE 2035, ECE 2036, ECE 3020, and ECE 3056.
- EDA provides 1 problem from ECE 2040 and 1 problem from ECE 3400.
- EMAG provides 1 problem from ECE 3025 and 1 problem from ECE 4350.
- Power provides 1 problem from ECE 3072 and 1 problem from ECE 3300.
- Microsystems provides 1 problem from ECE 3040 and 1 problem from the material in ECE 3450 and ECE 4752.
- BIO provides 2 problems from the material covered in ECE 4781, ECE 4782, and ECE 4784.
- Systems and Controls provides 2 problems from the material covered in ECE 3084 and ECE 3550.
- VLSI provides 1 problem from ECE 2020, 1 problem from ECE 3030, and 1 problem from ECE 3150.
- Optics provides 1 problem from ECE 4500 and 1 problem from ECE 4502.
- Telecom and DSP provide 1 problem from ECE 2026, 1 problem from ECE 3077, and 1 problem from ECE 3600.

The relevant courses are listed below:

Core Courses:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Department</th>
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</thead>
<tbody>
<tr>
<td>2020</td>
<td>Fund of Dig. Sys. Design</td>
<td>VLSI</td>
</tr>
<tr>
<td>2026</td>
<td>Into to Signal Processing</td>
<td>DSP</td>
</tr>
<tr>
<td>2035</td>
<td>Programming for HW/SW</td>
<td>CSS</td>
</tr>
<tr>
<td>2036</td>
<td>Eng Software design</td>
<td>CSS</td>
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<tr>
<td>2040</td>
<td>Circuit Analysis</td>
<td>EDA</td>
</tr>
<tr>
<td>3020</td>
<td>Mathematics for CE</td>
<td>CSS</td>
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<tr>
<td>3025</td>
<td>Emag</td>
<td>Emag</td>
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<tr>
<td>3030</td>
<td>Phys Foundations for CE</td>
<td>VLSI</td>
</tr>
<tr>
<td>3040</td>
<td>Microelectronic circuits</td>
<td>MicroSystems</td>
</tr>
<tr>
<td>3056</td>
<td>Arch, Concur, Energy in Comp</td>
<td>CSS</td>
</tr>
<tr>
<td>3072</td>
<td>Energy Systems</td>
<td>Power</td>
</tr>
<tr>
<td>3077</td>
<td>Prob and Stat for ECE</td>
<td>DSP/Telecom</td>
</tr>
<tr>
<td>3084</td>
<td>Signals and Systems</td>
<td>Controls</td>
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Breadth Courses:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Department</th>
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<tbody>
<tr>
<td>3400</td>
<td>Analog Electronics</td>
<td>EDA</td>
</tr>
<tr>
<td>3150</td>
<td>VLSI and Adv. Dig Design.</td>
<td>VLSI</td>
</tr>
<tr>
<td>3450</td>
<td>Semiconductor Devices</td>
<td>MicroSystems</td>
</tr>
<tr>
<td>Course Code</td>
<td>Course Title</td>
<td>Department</td>
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<tr>
<td>4350</td>
<td>Electromagnetic and Microwave Applications</td>
<td>Emag</td>
</tr>
<tr>
<td>3300</td>
<td>Energy Conversion</td>
<td>Power</td>
</tr>
<tr>
<td>3600</td>
<td>Computer Communications</td>
<td>Telecom</td>
</tr>
<tr>
<td>3550</td>
<td>Feedback Control Systems</td>
<td>Controls</td>
</tr>
</tbody>
</table>

**Undergraduate Elective Courses:**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Department</th>
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</thead>
<tbody>
<tr>
<td>4500</td>
<td>Optical Engineering</td>
<td>Optics</td>
</tr>
<tr>
<td>4502</td>
<td>Fiber Optics</td>
<td>Optics</td>
</tr>
<tr>
<td>4752</td>
<td>Int Circuit Fabrication</td>
<td>Microsystems</td>
</tr>
<tr>
<td>4781</td>
<td>Biomed Instrumentation</td>
<td>Bio</td>
</tr>
<tr>
<td>4782</td>
<td>Biosystems Analysis</td>
<td>Bio</td>
</tr>
<tr>
<td>4784</td>
<td>Electrophysiology</td>
<td>Bio</td>
</tr>
</tbody>
</table>

**Calculator Policy:**

Calculators that are approved for use on the Preliminary Exam are the same ones that have been approved for use on the Fundamentals in Engineering professional certification exam [http://ncees.org/exams/calculator-policy](http://ncees.org/exams/calculator-policy). These are readily available from Barnes & Noble, Office Depot, and other nearby stores.

Students wishing to use calculators that are not on this list must file a request through the "Contact Us" site a minimum of one week in advance of the exam. Include in your request a link to the website where the model and features of the calculator to be considered are described. Approval will be considered for any calculator that has the capabilities up to and including two-line alphanumeric displays, function/integral/derivative solvers, complex number calculations, and octal/hex conversions.

You MAY NOT use calculators with graphing capabilities, matrix or differential equation solvers, or advanced programming capabilities, including loops, function calls, memory stacks, etc.

Your calculator will be examined prior to the exam. Only those listed at the above website or pre-approved by the Graduate Office will be allowed during the exam. The exam proctors will be strictly enforcing this policy during the test period, and the use of such calculators during the exam will be considered a violation of exam policies and result in failure.
The CSS TIG provides 2 problems from the material covered in ECE 2035, ECE 2036, ECE 3020, and ECE 3056. The two specific courses that the problems are selected from are announced prior to the examination.

**ECE 2035 - Programming for Hardware/Software Systems**

Introduction to High Level Language and Assembly Programming

High Level Programming Language Syntax

Processing: ISA datapath and controller

Control: conditionals, iteration, recursion

Storage
   - static
   - stack
   - heap

Supporting Procedural Abstraction
   - procedure calling
   - activation frames

Supporting Data Abstraction
   - structs
   - arrays
   - linked lists
   - hash tables

Compilation, assembly, linking, loading, libraries

File Systems and I/O

Exception and Interrupt Handlers

Software Performance & Reliability
   - testing
   - debugging
   - performance monitoring

Embedded Software
   - interaction with the execution platform
   - energy efficiency

Basic Concurrency in Multicore Systems
   - data-level parallelism
   - support for atomicity

Optional Advanced Topics:
Dynamic typing

Automatic storage reclamation (garbage collection)

Security issues (e.g., software protection against buffer overflow or heap exploits)

**ECE2036 - Engineering Software Design**

*Required Topics:*
- Review of C basic syntax, compilation, linking, libraries, etc.
- Defining and implementing classes, constructors, destructors etc.
- Member functions, virtual functions, pure virtual functions
- Argument passing variations (by value, by pointer, by reference)
- Managing dynamic memory (new, delete)
- Inheritance and subclassing
- Using common tools, gdb, make, gprof, valgrind, emacs etc.
- Floating Point precision and numerical analysis
- Introduction to Templates, including data structures and algorithms in the Standard Template Library
- Parallel processing and concurrency

*Optional Topics:*
- Exceptions
- Smart Pointers

*Typical Programming Projects:*
- One dimensional and two dimensional Fast Fourier Transforms, using the Cooley-Tukey algorithm
- Matrix multiplication using dynamic memory allocation for arbitrary sized matrices, and efficient representation for sparse matrices.
- Wireless path loss computation through free space and obstructions.
- Shortest path discovery with obstacles.
- Image filtering and noise reduction in images.
- Optimal path planning with environmental constraints given at run-time.
- Localizing an arbitrary object in a visual image
- Optimal (and non-optimal) search for solving a problem with multiple solutions

**ECE3020 - Mathematical Foundations of Computer Engineering**

Iteration and Recursion
- Iteration
- Mathematical induction
- Recursion
- Recurrence equations
- Computational complexity.
- Example applications: parity coding, fast Fourier transform, complexity analysis of recursive programs.
Combinatorics and Probabilistic Methods
- Permutations
- Selections
- Inclusion-exclusion
- Probability spaces
- Conditional probability
- Independence
- Expectation.
- Example applications: expected running time, Monte Carlo methods, randomized algorithms.

Data abstractions
- Trees
- Lists
- Sets
- Relational data
- Graphs
- Example applications: network flow, circuit partitioning and routing, Huffman codes, decoding of error control codes.

Advanced Topics
- Automata theory
- state minimization
- regular expressions
- context-free grammars.
- Example applications: state machine design, pattern matching, parsing for compilation.

**ECE3056 - Architecture, Concurrency, and Energy in Computation**

Instruction Set Architectures
- Instructions, addressing modes, and sample ISAs
- Multi-cycle data path and control
- Controller implementation: state machine vs. microprogramming

Pipelining
- Pipelining basics
- Pipeline stages: fetch, decode, execute, memory write-back
- Hazards and solutions
- Branch prediction and delayed branches
- Case Studies

Memory Systems
- Basic organization of caches and main memory
- Virtual memory basics, memory management

Concurrency
- Evolution to multicore
- Introduction to synchronization primitives and the concept of data coherence
- Basics of message passing communication

Parallelism
- ILP, DLP, TLP
- Basic architectural support mechanisms

I/O Architectures
- Buses and interconnects
- Interrupts, DMA, polling
- Disk structures, I/O scheduling
- LANs, network interfaces, & basic interprocessor communication
- Case Studies

Energy and Power dissipation
- Dynamic and static energy dissipation fundamentals
- Microarchitecture-level energy dissipation and power models
- Power virus, kernel benchmarks and power
- Basics of voltage and frequency scaling
- Case studies
EDA provides 1 problem from ECE 2040 and 1 problem from ECE 3400

ECE2040 - Circuit Analysis

Basic Concepts
- Voltage, Current, Power and Energy
- Circuit elements (R, L, C, ideal operational amplifiers, ideal transformer)
- Independent and Dependent Sources
- Kirchhoff's Laws
- Series and Parallel Combinations of Elements
- Voltage Division and Current Division

DC circuit analysis
- Node Analysis
- Mesh Analysis

Network Theorems
- Linearity
- Superposition
- Source Transformations
- Thevenin's Theorem
- Norton's Theorem

Circuits Containing Operational Amplifiers
- Ideal Op Amp model, with negative feedback condition
- Inverting and Non-Inverting Configurations
- Voltage Followers, Adders, Difference Amplifiers

First and Second-Order Circuits
- Singularity Functions
- RC and RL Source-Free Circuits
- Constant and Non-Constant Forcing Functions
- Initial and Final Values
- Op-amp circuits for integration and differentiation
- Measurement of signals in physical circuits
- RLC circuits
- Time-Domain Analysis

Sinusoidal Steady-State (SSS) Analysis
- Sinusoids
- Complex Numbers
- Complex Exponential Representations of Sinusoids (Phasors)
- Impedance and Admittance
- Superposition, Thevenin's and Norton's Theorems
- Analysis and Network Theorems for SSS
- Frequency response
- Bode plots
- Resonance
- Measurement of frequency response of physical circuits
Power Analysis
- Instantaneous and Average Power
- Power Factor and Power Factor correction
- Complex Power
- Maximum Power Transfer

ECE3400 - Analog Electronics

Review
- Small-signal and large-signal models of the diode, the BJT, the JFET, and the MOSFET

Single Stage Amplifiers
- BJT and FET single-state amplifiers
- Biasing, voltage gain, input resistance, and output resistance

Multi-State Amplifiers
- Differential, cascade, and cascode amplifiers
- Biasing, voltage gain, input resistance, and output resistance

Transfer Function Analysis
- First-order low-pass, high-pass, and shelving functions
- Second-order low-pass, band-pass, band-reject, and biquadratic functions
- Bode plots
- Passive single time-constant circuits
- Passive second-order resonant circuits

Frequency Response of Amplifiers
- Method of short-circuit time constants for low-frequency analysis of single-stage amplifiers
- High-frequency small-signal device models
- Method of open-circuit time constants for the high-frequency analysis of single-stage amplifiers

Active Filters
- Butterworth and Chebyshev filter approximations
- Second-order Sallen-Key and infinite-gain multi-feedback low-pass, high-pass, band-pass, and band-reject filter topologies
- Third-order and higher-order filters

Feedback Amplifiers
- Effects of feedback on gain, input resistance, output resistance, noise, distortion, and bandwidth
- Series-shunt, shunt-shunt, series-series feedback topologies

Non-linear Applications of Op-Amps
- Waveshaping circuits
- Precision rectifiers
- Peak detectors.
Feedback Oscillators and Function Generator Circuits
- Sinusoidal oscillators
- Bistable multivibrators
- Waveform generators.
EMAG provides 1 problem from ECE 3025 and 1 problem from ECE 4350

**ECE3025 - Electromagnetics**

Electrostatics
- Scalar Potential, Energy Density, Force
- Electrostatic Field of Charge Distributions
- Permittivity (Dielectric Constant)
- Boundary Conditions
- Concept of Capacitance

Electric Current
- Equation of Continuity
- Electrical Conductivity and Resistance

Magnetostatics
- Vector Potential, Energy Density, Force
- Magnetostatic Field of Current Distributions
- Permeability
- Boundary Conditions
- Concept of Inductance

Time-Varying Fields
- Maxwell's Equations
- Transformers
- Motors and Generators
- Energy, Power and Poynting's Theorem
- Time-Harmonic Fields

Transmission Lines
- Lumped Circuit Model
- Transmission Line Equations
- Pulse Excitation
- Time-Harmonic Excitation
- Matching

Plane Waves and Geometric Optics
- Concept of a Plane Wave, Polarization
- Fresnel's Equations
- Lossy Media, Skin Depth
- Lenses and Mirrors
- Overview of Optical Fibers

Radiation
- Hertzian Dipole
- Antenna Parameters (Directivity, Beamwidth, etc.)
- Aperture Antennas
- Friis Transmission Formula
ECE4350 - Electromagnetic and Microwave Applications

Impedance Matching Techniques
- Use of the Smith Chart
- Quarter-wave matching
- Stub tuning

Transmission Lines & Waveguides
- General Principles
- Stripline
- Microstrip
- Parallel Plate Waveguides
- Rectangular Waveguides

Resonators
- Transmission Line Resonators
- Rectangular Waveguide Cavities

Microwave Device Analysis
- S Parameters
- Power Dividers
- Directional Couplers & Hybrids

Filter Design
- Insertion Loss Method
- Filter Transformations

Antennas
- Antenna Parameters (Directivity, Beamwidth, etc.)
- Wire Antennas (Dipoles, Loops)
- Principles of Aperture Antennas (Horn, Reflector)
Power provides 1 problem from ECE 3072 and 1 problem from ECE 3300

**ECE3072 - Electrical Energy Systems**

Energy Requirements, Resources, and Sustainability.
- Modern societal energy requirements
- Electricity consumption across the US, options for reducing demand
- Non-Renewable sources of energy: coal, oil, natural gas, and nuclear reserves, energy density, economic costs
- Renewable sources of energy: hydro, geo-thermal, photovoltaic, wind, tidal, ocean-wave, biomass, and ethanol; energy density, and economic costs.
- Long term sustainability of these energy sources.

Conversion of Non-Renewable and Renewable Energy Sources to Electric Energy.
- Advantages of electric energy
- Fundamental structure, quantitative analysis, and efficiency of different sources
- Cost per unit of electric energy produced, safety issues
- Environmental impact of energy conversion processes, trade-offs with process efficiency
- Economic, political, and infrastructure barriers to the conversion from non-renewable energy sources to renewable sustainable sources of energy

Principles of Electric Power Delivery
- Significance of the lack of energy storage in the electric power system
- Fundamentals of three-phase power, including per-phase calculations, complex power, power factor and utility billing practices
- Equivalent circuit model of generators, transformers, lines and loads; need for VAR compensation
- Simple two-bus system to demonstrate principles of power flow, stability, and other constraints
- Electric Safety
- Electric shock, body resistance, and grounding

Principles of Electric Energy Processing and Conversion
- Matching source characteristics to load requirements
- Principles of power electronic converters; types of power converters (dc/dc, ac/dc and dc/ac); duty cycle control, filtering, input-output characteristics, efficiency and dynamic response
- Power supplies for electronic equipment, characteristics, limitations and challenges
- Electromechanical systems based on variable reluctance principles: solenoids, stepper motors, and transducers
- Rotating electromechanical transducers: brushed and brushless dc- and induction-machines
- Principles of power electronic variable speed drives for rotating transducers
- System considerations including dynamics, control, load interaction and utility grid interface issues including power-factor, harmonics, and start-up

**ECE3300 - Electromechanical and Electromagnetic Energy Conversion**
Energy: Technology and Resources
- Energy resources: quantity and estimation of reserves
- Fossil fuel electric energy production
- Nuclear fuel electric energy production
- Solar energy conversion
- Other energy production technologies

Three-Phase Systems and Power Systems
- Real and reactive power
- Three phase systems
- Y and Delta connections and transformations
- Electric energy transmission and distribution systems, AC versus DC

Magnetic Circuits
- Properties of magnetic materials
- Ampere's law and magnetic circuits
- Faraday's law and induced voltages
- Permanent magnets
- Induction and coupled magnetic circuits
- Analysis and mitigation of electromagnetic noise

Transformers
- Ideal transformer
- Physical model and equivalent circuits
- Transformer testing

Electromechanical Energy Conversion
- Electromagnetic energy storage
- System energy conservation
- Forces, Lorentz torque, and reluctance torque
- Examples of simple energy conversion structures

Efficiency and Process Performance
- Losses and heat production in electrical systems
- System efficiency and performance

Sensors and Actuators
- Electromechanical relays
- Stepper and positioning systems
- Switched reluctance machines
- Synchronous reluctance machines
- Concept of DC machines

Symmetrical AC Synchronous Machines
- Limit the presentation to round rotor machines
- MMF of a distributed winding and rotating magnetic fields
- Torque in rotating machines
- Motor ratings and capability
- Equivalent circuit
Symmetrical AC Induction Machines
- Construction and layout
- Rotor field and slip
Microsystems provides 1 problem from ECE 3040 and 1 problem from the material in ECE 3450 and ECE 4752

ECE3040 - Microelectronic Circuits

Basic Semiconductor Physics
- Bonding Mechanisms
- Charge Carriers
- Generation/Recombination
- Doping
- Carrier Transport
- Optical Absorption

PN Junctions
- Equilibrium Analysis
- Carrier Transport Under Applied Bias
- Transient Properties
- Diode Circuit Models
- Diode Applications (LEDs, Detectors)
- Diode Circuits (Limiting, Clamping, Rectifying Circuits)
- SPICE Analysis

Bipolar Junction Transistor
- Structure
- Circuit Symbol and Terminal Characteristics
- BJT Physics: Equilibrium and Under Applied Bias
- Ebers-Moll Model
- Small Signal Model
- SPICE Analysis

MOS Field Effect Transistors
- MOS Capacitor
- MOS Electrostatics
- MOSFET Structure, Symbol and Terminal Characteristics
- MOSFET Device Physics
- Circuit Models
- SPICE Analysis

Single Stage Amplifiers
- General Concepts
- Common Emitter/Source
- Common Base/Gate
- Common Collector/Drain
- Differential Amplifiers
- SPICE Analysis

Operational Amplifiers
- Inverting/Non-inverting Configurations
- First Order Circuits
- Frequency Response
- Non-ideal Performance

Digital Circuits
- Inverter Characteristics and Circuits
- Gates (AND/NAND, OR/NOR)
- CMOS Inverters and Gates
- CMOS and BiCMOS Logic

**ECE3450 - Semiconductor Devices**

System Application Background
- Current and future computer systems
- Current and future fiber optic and wireless communication systems

General Limits/Capabilities of Existing Technologies
- Silicon device characteristics

Review of Semiconductor Device Basics
- Band structure
- Doping and impurities
- Device physics for p-n junctions

Specific Devices for Computers, Wireless and Fiber:
- Mixers (AC characteristics of p-n junctions, junction and diffusion capacitance, nonlinear issues)
- FETs - Silicon MOSEFT's (MOS Capacitor, threshold voltage, capacitance effects, self-aligned gates, short-channel effects, basics of CMOS logic families, etc.)

BJTs
- Basic-device operation
- High-speed Silicon BJTs (DC characteristics)
- GaAs-based HBTs (DC characteristics, RF characteristics)

Sources (emitters)
- LEDs, (e.g., color, electron-hole annihilation, generation/recombination)
- Semiconductor Lasers (Fabry Perot structure, cleavage planes and mirror surfaces, AR & HT coatings, simple models for laser operation, DFB and DBR lasers)

Detectors
- Photodiodes (optical absorption, minority carrier injection, factors affecting speed)
- Avalanche photodiodes (carrier multiplication, noise, superlattice structures, speed)

Fabrication Issues:
- Integrated Circuit Fabrication
  - Fabrication of monolithic circuits
  - The computation-interconnection balance
  - Testing and packaging
  - Yield and fabrication economics
- VLSI Scaling
  - Self-consistency
  - Ideal and practical scaling
  - Fundamental and practical limits to scaling
  - The influence of parasitics and interconnect

**ECE4752 - Integrated Circuit Fabrication**

Overview of Silicon Processing
Crystal Growth and Doping
Substrate Characterization
Oxidation
Photolithography
Etching
Diffusion
Ion Implantation
Metallization
Epitaxial Growth and CVD
SUPREM Simulation
Device Characterization and Measurement
CMOS Process Integration
Bonding and Packaging
Yield
The Bioengineering TIG provides two problems selected from either ECE4781, ECE4782 and ECE 4784

**ECE4781 – Biomedical Instrumentation**

Basic Concepts of Instrumentation
- Static and dynamic characteristics
- Design criteria
- Instrumentation Amplifiers

Membrane Biophysics
- Diffusion across cell membranes
- Nernst potentials
- Diffusion potentials
- Goldman equation

Action Potentials
- Membrane behavior
- Origin of action potential
- Hodgkin-Huxley equations
- Modeling
- Propagation of action potentials
- Subthreshold stimuli

Biopotential Electrodes
- Fundamentals
- Body surface electrodes
- Microelectrodes

Electrophysiology of the Heart
- Anatomy/physiology of heart
- Body surface potentials
- Electrocardiogram
- Heart vector
- Standard leads

Electrophysiology of Neuromuscular System
- Neuromuscular Junction
- Transmitters
- Poisson statistics for transmitters
- Postjunctional response
- Anatomy/physiology of muscle
- Myofibrils and filaments
- Excitation contraction
- Electromyography
- Functional neuromuscular stimulation

Miscellaneous Electrophysiology
- Electroencephalography
- Electroretinogram

- Biomedical Transducers
  - Displacement transducers
  - Thermocouples and thermistors

Measurement of Blood and Gas Flows
- Electromagnetic flowmeter
- Ultrasonic flowmeter
- Thermodilution catheter

**ECE 4782 – Biosystems Analysis**

Fundamentals of digital signals and systems
- Convolution
- Fourier transform
- Digital filters

Fundamentals of probability and statistics
- Probability distribution and density functions
- Expectation and moments
- Random processes
- White noise
- Correlation analysis
- Linear Regression
- Examples of biostatistics: independence, dependence, genetic counseling, false alarm

Modeling biological systems
- Models of systems and the modeling process
- Qualitative model formulation
- Quantitative model formulation
- Simulation paradigms
- Numerical techniques
- Parameter estimation
- Model validation
- Model analysis
- Stochastic models
- Nonlinear models

Applications/examples
- Driver controlling speed of automobile
- Latency characteristics
- Pupil response
- Electroretinogram
- Adaptive noise cancelation
- Neural information processing

**ECE4784 - Engineering Electrophysiology**
Membrane Biophysics
- Diffusion across cell membranes
- Nernst potentials, Diffusion potentials
- Goldman equation

Action Potentials
- Membrane behavior, Origin of action potentials
- Hodgkin-Huxley equations, Modeling
- Propagation of action potentials
- Subthreshold stimuli

Extracellular Fields
- Monopole and dipole models

Cellular Analysis Technologies
- Coulter counter
- Impedance spectroscopy, Fluorescence spectroscopy
- Molecular tagging
- Electrodes

Electrophysiology of the Heart
- Anatomy/physiology of the heart, Heart vector
- Electrode configurations, Recording
- Body surface potentials, Interface electronics

Neuromuscular Junction
- Transmitters
- Poisson statistics
- Post-junctional responses

Skeletal Muscle
- Anatomy/physiology of muscle
- Myofibrils and filaments
- Excitation contraction

Functional Neuromuscular Stimulation
- Electrodes
- Nerve excitation

Interface Circuitry and Systems
- Neurophysiological analysis systems
- Skeletal muscle interfaces
- Blood Analysis

Advanced Electrophysiological Analysis Systems
- Micro systems
- Metabolite monitoring
- Prosthetic devices / bionics
Systems and Controls provides 2 problems from the material covered in ECE 3084 and ECE 3550

ECE3084 - Signals and Systems

Introduction and motivation
- Engineering approximations and mathematical abstractions
- Continuous-time vs. discrete-time signals and systems
- Linear systems (superposition)
- Time invariance

Frequency-domain signal analysis
- Fourier series
- Continuous-time Fourier transforms
- Properties of Fourier transforms

Frequency-domain characterizations of linear systems
- Transfer functions (jw)
- Frequency responses

Time-domain characterizations of linear systems
- Differential equations
- Convolution
- Lumped vs. distributed systems

Discrete-time representations of continuous-time signals
- Nyquist sampling
- Filters (A/D -> filter -> D/A cascade)

Laplace-domain signal analysis
- Forward and inverse Laplace transforms
- Properties of Laplace transforms
- Initial and final value theorems
- Convolutions
- Connections between Fourier and Laplace transforms

Laplace-domain characterizations of linear systems
- States
- Laplace-domain representation of ODEs
- Transfer functions (s); poles and zeros
- Responses (zero state, zero input)
- Laplace-domain electric circuit analysis
- Stability
- Feedback
Continuous-Time Systems
- Basic Concepts
  - Excitation from External Energy Sources and Internal Energy Storage
  - Zero-State Response and Zero-Input Response
- Review of Laplace Transform
  - Pairs and Properties
  - Partial Fraction Expansion
- Differential Equations
  - Input-Output Representation
  - Solution by Transform Techniques
- Systems Modeling from Physical Principles
  - Electric Circuits
  - Mechanical Systems
  - Electromechanical Systems
  - Heat and Fluid-Flow Systems
- System Stability
  - External (BIBO) Stability, Stability of Zero-State Response, Poles
  - Internal Stability, Stability of Zero-Input Response, Modes
  - Routh-Hurwitz Criterion

Feedback Control Systems
- Basic Concepts
  - Unity-Feedback Configuration
  - PID, Lag and Lead Compensators
  - Effects of Feedback
  - Performance Criteria for Design
- Fundamentals of Control Systems Design
  - Tracking of a Reference Signal
  - Disturbance Rejection
  - Sensitivity Reduction
- The Root-Locus Design Method
  - Root Locus Plots
  - Desired Pole Region
  - Dynamic Compensation
  - Design Examples
- The Frequency-Response Design Method
  - Nyquist Stability Criterion
  - Bode Plots and Stability Margins
  - Dynamic Compensation
  - Design Examples
VLSI provides 1 problem from ECE 2020, 1 problem from ECE 3030, and 1 problem from ECE 3150

ECE2020 - Fundamentals of Digital System Design

Introduction to Computing Systems
- building complex systems out of simple elements
- examples in today's products
- architecture block diagram

Switch Design
- behavior vs. implementation truth tables
- switch combinations: series and parallel
- semiconductor switches: n-type & p-type
- implementing logical functions
- implementing basic gates
- introduction to VLSI technology

Boolean Algebra
- Boolean expressions & algebra
- DeMorgan's square & DeMorgan's theorem
- standard forms: SOP/POS using min/max terms

Gate Design
- designing with gates vs. switches
- decoupling behavior and implementation using mixed logic
- implementing SOP and POS expressions
- gate delay and energy dissipation
- pass gates and floating outputs

Simplification
- expression simplification
- 2, 3 and 4 variable Karnaugh maps
- negative logic and don't cares

Building Blocks
- powers of two, working with binary
- encoders/decoders
- pass gates and tri-state outputs
- multiplexers/demultiplexers
- programmable logic arrays

Number Systems
- notations: decimal, binary, hexadecimal
- representations: unsigned vs. two's complement
- representations: integer, fixed point and floating point
- symbolic representations

Arithmetic
- addition and subtraction
- ranges and resolutions
- error and overflows
- adder/subtractor implementation

Latches and Registers
- combinational vs. sequential logic
- bistable element using basic gates
- RS latch and transparent latch
- shift register and register
- two-phase non-overlapping clocking
- edge vs. level triggering; read/write enables
- energy and power in a clocked system

Counters
- basic toggle cell operation
- building binary counters
- building divide-by-N counters
- cascading multi-digit counters

State Machines
- state machine operation
- transition diagrams and tables
- state machine implementation: Moore and Mealy
- state machine operation in behavioral HDL
- in-class mini-lab: state maching

Memory
- memory cell behavior and protocol
- static random access memory (SRAM) cell
- dynamic RAM (DRAM) cell
- memory chip organization
- building memory systems
- bit, byte and word addressing
- alignment, byte order

Datapaths
- operands: register file and immediate values
- three bus architecture
- execution units: arithmetic, logical, shift
- memory interface

Introductory Assembly Programming
- basic computer organization
- instruction formats
- datapath operations: arithmetic, logical, shift, memory
- conditional execution (if-then-else)
- basic loops (while)
ECE3030 - Physical Foundations of Computer Engineering

Introduction to a digital information processing system

Fundamental principles and requirements of representations of a bit
- distinguishability and conditional change of states
- physical implementation of a bit - Barrier Model and other models

Physics of CMOS based Computation - Barrier Model
- Use of energy barrier to represent and modulate a bit
  - Relation to semiconductor physics
- Engineering energy barrier in practice
  - MOSFET and device physics
  - Switches as computing devices
- Physics of interconnected switches to process information
  - Relationship to RC circuit analysis
- Physics of data communications via signal propagation through wire
  - Relationship to electromagnetism and Transmission lines
- Physical attributes of a computing system
  - Performance, Energy, and Robustness/Error
  - Relation to semiconductor physics, circuit theory, and wires
  - Interaction of performance, energy, and robustness
  - Understanding the physical limits CMOS circuits

Other computing systems and models
- Fundamentals of CMOS based analog computing
- Alternative computing models - e.g. concepts of quantum computing, biological computing etc.

ECE3150 - VLSI and Advanced Digital Design

Design Methodology

Switches and Layout
- Switch based design
- Complex gates
- Layout and technology
- Registers
- Adders

Circuit design issues
- MOSFET models
- Delay models
- Hazards, metastability, synchronization
- Alternate logic structures
- Timing and clocking
- Power models
- Sleep transistors
Advanced digital issues
- Logical effort
- Ideal number of stages
- Asymmetric gates
- Calibrating the model
- Branches and Interconnect

5. Test Logic (1 week)
   a. Combinational test
   b. Sequential test
   c. Scan design

6. Advanced Modules (2 weeks)
   a. ROM, PLA
   b. Advanced adders
   c. Multipliers
   d. Barrel shifter
   e. Decoders
Optics provides 1 problem from ECE 4500 and 1 problem from ECE 4501

**ECE4500 - Optical Engineering**

Optical Sources and Measurements
- Introduction
- Blackbody Radiator
- Line Sources / Light Emitting Diodes (LED)
- Lasers
- Coherence (Spatial Coherence/Temporal Coherence)
- Radiometry / Photometry

Geometrical Optics (Image Formation)
- Introduction
- Prisms
- Reflection and Refraction at a Spherical Surface
- Thin and Thick Lenses
- Optical Components
  - Lenses, Mirrors, Prisms, Beam Splitters
- Aberrations in Optical Systems
- Optical Instruments
- Fiber Optics

Wave Optics
- Polarized Light
  - Reflection and Refraction
  - Brewster's Angle
- Interference
- Diffraction
  - Fraunhoffer
  - Fresnel
- Grating Diffraction
- Laser Doppler Velocimeter

Optics of Transformations
- Optical Fourier Transforms
- Holography
  - Production of Holograms
  - Holographic Nondestructive Testing
- Optical Data Processing
  - Pattern Recognition
  - Image Enhancement
- Optical Memories

Light and Matter
- Birefringence
- Electro-optic, Magneto-optic and Acousto-optic Devices
- Optical Detectors
- Optical Recording Materials
- Optical Displays
  - Alphanumeric Displays
  - Image Displays
- Optical Communications Systems
- Optical Displays
  - Alphanumeric Displays
  - Image Displays
- Optical Communications

**ECE4501 - Fiber Optics**

Review of Waveguiding Principles
- Review of Selected Topics in Optics
- Wave Equation and General Solutions
- Wave Propagation in Symmetric Dielectric Slab Waveguides
Field Solutions for Step-Index Fibers
- Weakly Guiding Approximation
- Wave Equation Solution
- Mode Description and Cutoff Conditions
- Power Confinement
Signal Degradation in Step-Index Fibers
- Absorptive, Radiative, and Scattering Losses
- Dispersion
  - Dispersion Mechanisms in Single-Mode Fiber
  - Group Delay Distortion in Multimode Fibers
  - Optical Pulse Propagation and Broadening
Power Launching and Coupling
- Gaussian Beams; Use of Lenses
- Basic Considerations for Optimum Coupling
- Coupling Efficiency Determination
Sources for Optical Communication Systems
- Basic p-n Junction Devices
- Light-Emitting Diodes; Semiconductor Lasers
Photodetectors
- PIN Photodiodes; Avalanche Photodiodes
- Response Time; Photodetector Noise
Transmission Links
- Basic System Design; System Budget Considerations
- Multiplexing Techniques
- Codes for Optical Communication Systems
Optical Networks
- Passive Components; 3 dB Couplers and Stars
- Optical Switching and Switch Architectures
- Network Architectures; Approaches to Optical Management
- Optical Amplifiers; Operation and Impact
Laboratory Characterization of Components
- Gaussian Beams
- Semiconductor Sources
- Detectors
- Fiber Loss and Dispersion
- Application of Advanced Measurement Techniques and Equipment
- Optical Spectrum Analyzer
- Optical Time Domain Interferometer
- Bit Error Rate Test Set
- Eye-Diagram Analysis
- Polarization Analysis
Telecom and DSP provide 1 problem from ECE 2026, 1 problem from ECE 3077, and 1 problem from ECE 3600.

ECE 2026 – Introduction to Signal Processing

Sinusoidal Signals
- Amplitude, Phase & Frequency
- Complex Exponential Representation (Phasors)

Spectrum Representation of Signals
- Sinusoids, Harmonics
- Other Synthesis Examples: e.g., Chirp (FM) Signals
- Spectrogram Analysis
- Fourier Series: Synthesis & Analysis

Digital Signals and Sampling
- Aliasing & Folding
- Reconstruction from Samples
- Relationship between Continuous-Time and Discrete-Time Frequency Domains

Moving Average Filters
- Finite-Length Impulse Response (FIR)
- Convolution
- Linearity & Time-Invariance

Frequency Response
- Magnitude & Phase Response
- Lowpass, Highpass & Bandpass Filters

Z-Transform Method for FIR
- Zeros of the Transfer Function Polynomial
- Cascading Systems
- Relationship to Frequency Response

Recursive Filters
- Feedback Difference Equations
- Infinite-Duration Impulse Response
- Z-transform for Recursive Filters
- Second-Order (Narrowband) Filters

Laboratory Modules will include:
- Introduction to MATLAB software
- Manipulating Sinusoids & Complex Exponentials
- Synthesis from a Spectrum (Fourier Series Analysis)
- Sound and Music Synthesis
- Frequency Response for Digital Filters
- Filtering Applications
  (e.g., AM Demodulation of Touch-Tone Phone)
- Filter Banks, e.g., Cochlear Implant Simulation
- Implementation of Digital Filters on DSP Chips
- Image Enhancement Applications
- Simulation of Differential Equations
- Periodic x(t) thru Analog System: Filter the Fourier Series
- Time-Frequency Analysis of Signals (Spectrogram)

ECE3077 - Introduction to Probability and Statistics for ECE

Introduction to Probability
- sets, axioms of probability
- basic combinatorics and counting
- independence, conditional probability
- inference using Bayes'™ rule
- Applications to ECE: radar detection, transmission of digital information, network connectivity and reliability

Random Variables
- densities and distribution functions (discrete and continuous)
- expectation and moments
- the moment generating function
- example distributions (Bernoulli, Binomial, Geometric, Poisson, Gaussian, Exponential, etc)
- Applications to ECE: noise in electronic circuits, queueing in networks, cache in computers, bit errors in communications, modeling failure times, probability models for speech and optical character recognition, modeling optical communication systems

Multiple Random Variables
- joint densities and distributions
- conditional densities and conditional expectation
- independence, correlation, and covariance
- multidimensional Gaussians, covariance matrices
- joint functions of random variables
- sums of random variables
- Applications to ECE: modeling manufacturing variation, modeling dependencies in natural language, signal detection, signals in additive and multiplicative noise

Limit Theorems
- the central limit theorem
- law of large numbers
- Applications to ECE: analysis and modeling of photodetectors, polling, modeling noise in instrumentation

Random Sequences
- the Bernoulli process
- the Poisson process
- Markov chains and random walks
- Applications to ECE: task scheduling, Markov models of language for speech processing, queueing in network routers

Basic Statistics
- sample mean and variance
- confidence intervals
- hypothesis testing
- curve-fitting and regression
- parameter estimation
- Applications to ECE: detection in digital communications, direction-of-arrival estimation, target tracking

Further Topics of Probability and Statistics in ECE
- generating random numbers
- Monte Carlo simulations
- entropy and information
- average case analysis of algorithms

**ECE3600 - Computer Communications**

Introduction
- Classification of Communication Networks
- Switching Methods (Circuit Switching, Packet Switching)

Physical Layer
- Digital Data Communication Techniques
- Interfacing to Physical Layer

Data Link Layer
- Introduction
- Framing Techniques
- Error Detection/Correction Techniques
- Flow Control (Stop-and-Wait, Sliding Window)
- ARQ Error Control (Stop-and-Wait, Go-Back-N, Selective Repeat Request)
- Performance Analysis of ARQ Protocols

Circuit Switching
- Circuit Switched Networks
- Switching Concepts
- Routing in Circuit Switched Networks

Network layer
- Routing
- Traffic Control

Local Area Networks
- IEEE 802.3: Bus with CSMA/CD Protocol
- IEEE 802.5: Token Ring
- Fiber Distributed Data Interface (FDDI)
- Distributed Queue Dual Bus (DQDB)
- Fast Ethernet

Transport Layer
- Transport Protocol Mechanisms
- Flow Control and Congestion Control in TCP
- Transport Control Protocol
Internetworking
- Connectionless Internetworking
- The Internet Protocol
- Routing Protocol

Overview of ATM Networks
- Basic Concepts of ATM
- Multiplexing
- Broadband Switching
- ATM Cell Structure
- ATM Layer